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Report of the . . .  
South African  
Association for the  
Advancement  
of Science. .

Cape Town, 1908.



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**Association** for the  
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FIRST MEETING,  
Cape Town 1908.

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## CONSTITUTION OF THE ASSOCIATION.

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### I.—OBJECTS.

The objects of the Association are :—To give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of Societies and individuals interested in Science in different parts of South Africa; to obtain a more general attention to the objects of pure and applied Science, and the removal of any disadvantages of a public kind which may impede its progress.

### II.—MEMBERSHIP.

(a) All persons interested in the objects of the Association are eligible for Membership.

(b) The Association shall consist of Permanent Members, hereafter called "Members," and Temporary Members, hereafter called "Associates."

(c) Members shall be elected directly by the Council; Associates by Local Committees.

(d) The Council shall have the power, by a three-fourths vote, to remove the name of anyone whose Membership is no longer desirable in the interests of the Association.

### III.—PRIVILEGES OF MEMBERS AND ASSOCIATES.

(a) Members shall be eligible for all offices of the Association, and to serve on its Committees, and shall be entitled to a copy of all ordinary publications issued by the Association subsequent to the date of their election.

(b) Associates are eligible to serve on the Local Reception Committee, but are not eligible to hold any other office, and they are not entitled to receive gratuitously the publications of the Association.

### IV.—SUBSCRIPTIONS.

(a) The Annual Subscriptions for Members shall be One Pound, payable first at election, and thereafter on the First of July of each year. After the first session intending Members shall be required to pay an Entrance Fee of One Pound, in addition.

(b) A Member may at any time become a Life Member by one payment of Ten Pounds, in lieu of future Annual Subscriptions, or in lieu of Entrance Fee and future Annual Subscriptions.

(c) The Annual Subscription for Associates shall be Fifteen Shillings.

(d) The Council may authorise Local Committees to admit students as Associates at a reduced subscription on the special circumstances of each case being submitted.

#### V.—MEETINGS.

The Association shall meet in Session periodically for one week or longer. The place of meeting shall be appointed by the Council as far in advance as possible, and the arrangements for it shall be entrusted to the Local Committee, in conjunction with the Council.

#### VI.—COUNCIL.

(a) The Management of the affairs of the Association shall be entrusted to a Council.

(b) The Council shall, in the first instance, be elected by the General Committee, and shall consist of Twenty-five Members. Thereafter it shall consist of the President and four Vice-Presidents of the Association, Past Presidents of the Association, Past and Present General Secretaries and Treasurers, representatives to be elected by each Centre in the proportion of one representative for every 25 Members, and such others to be elected by the Members at the Annual Meeting of the Association, as shall give altogether one Member of Council to every 25 Members of the Association.

(c) The Council so elected shall at once proceed to elect the President, Vice-Presidents, two Secretaries, Treasurer, and an Assistant General Secretary. The Council shall have the power to pay for the services of the Assistant General Secretary, and for other such clerical assistance as it may consider necessary.

(d) During any Session of the Association the Council shall meet, at least, twice.

(e) The Council shall have power to frame Bye-laws to facilitate the practical working of the Association, so long as these Bye-laws are not at variance with the Constitution.

#### VII.—MANAGING COMMITTEE OF COUNCIL.

In the intervals between the Sessions of the Association, its general affairs shall be managed by a Committee of Council, consisting of President, General Treasurer, General Secretaries, and four other Members, elected annually by the Council.

## VIII.—LOCAL COMMITTEES.

In the intervals between the Sessions of the Association, its local affairs shall be managed by the Local Committees. This Committee shall consist of the Members of the Council resident in that Centre, with such other Members of the Association as the said Members of Council may elect.

## IX.—RECEPTION COMMITTEE.

The Local Committee of the Centre at which the Session is to be held shall form a Reception Committee, to assist in making arrangements for the meeting, and for the reception and entertainment of the visitors. This Committee shall have power to add to its number from among the Members and Associates of the Association.\*

## X.—HEADQUARTERS.

The Headquarters of the Association shall be in Cape Town at the outset.

## XI.—FINANCE.

(a) The Financial Year shall end on the 30th of June.

(b) All sums received for Life Subscriptions and for Entrance Fees shall be invested in the names of three Trustees appointed by the Council, and only the interest arising from such Investment shall be applied to the uses of the Association.

(c) Subscriptions shall be collected by the Local Secretary of each Centre, and by him forwarded to the General Treasurer.

(d) The Local Committees shall not have power to expend money without the authority of the Council, with the exception of the Local Committee of the Centre at which the next ensuing Session is to be held, which shall have the power to expend money collected, or otherwise obtained in that Centre. Such disbursements shall be audited, and the balance-sheet and the surplus funds forwarded to the General Treasurer a month before the end of the Financial Year.

(e) All Cheques shall be signed either by the General Treasurer and a General Secretary, or by the Local Treasurer and Secretary of the Centre at which the next ensuing Session is to be held.

(f) Whenever the balance in the hands of the Treasurer shall exceed the sum requisite for the probable or current expenses of the Association, the Council shall invest the excess in the names of the Trustees.

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\*For arrangements with regard to Papers to be read, see Section 14.

(g) The whole of the accounts of the Association, *i.e.*, the local as well as the general accounts, shall be audited annually by an auditor appointed by the Council, and the Balance-sheet shall be submitted to the Council at the first meeting thereafter, and be printed in the Annual Report of the Association.

## XII.—GRANTS FOR RESEARCH.

(a) Grants may be made by the Association to Committees or to individuals for the promotion of Scientific Research.

(b) Committees and individuals to whom grants of money shall be entrusted are required to present to the following Meeting a report of the progress which has been made, together with a statement of the sums which have been expended. Any balance shall be returned to the General Treasurer. In each Committee the Secretary is the only person entitled to call on the Treasurer for such portions of the sums granted as may from time to time be required. In making grants to money to Committees or to individuals, the Association does not contemplate the payments of personal expenses to the Members, or to individuals.

## XIII.—SECTIONS OF THE ASSOCIATION.

The Council shall have the power to constitute such sections of the Association as it may consider necessary, the following being constituted at the outset:—

- A. Astronomy.  
Chemistry.  
Mathematics.  
Meteorology.  
Physics.
- B. Anthropology and Ethnology.  
Bacteriology.  
Botany.  
Geography.  
Geology and Mineralogy.  
Zoology.
- C. Agriculture.  
Architecture.  
Engineering.  
Geodesy and Surveying.  
Sanitary Science.
- D. Archæology.  
Education.  
Mental Science.  
Philology.  
Political Economy.  
Sociology.  
Statistics.

## XIV.—SECTIONAL COMMITTEES.

(a) The Presidents, Vice-Presidents, and Secretaries of the several sections shall be chosen by the Council, after consultation with the Local Committee of the Centre at which the next ensuing Session of the Association is to be held.

(b) From the time of their election, which shall take place as soon as possible after the Session of the Association, they shall form themselves into an organising Committee for the purpose of obtaining information upon Papers likely to be submitted to the Sections, and for the general furtherance of the work of the Sectional Committees. The Sectional Presidents of former years shall be *ex officio* members of the Organising Committee.

(c) The Sectional Committee shall have power to add to their number from among the Members and Associates of the Association.

(d) The Committees of the several Sections shall determine the acceptance of Papers before the beginning of the Session, keeping the General Secretaries informed from time to time of their work. It is therefore desirable, in order to give an opportunity to the Committees of doing justice to the several communications, that each author should prepare an Abstract of his Paper of a length suitable for insertion in the published Transactions of the Association, and he should send it, together with the original Paper, to the Secretary of the Section before which it is to be read, so that it may reach him, at least, a fortnight before the Session.

(e) Members may communicate to the Sections the Papers of non-members.

(f) The Author of any Paper is at liberty to reserve his right of property therein.

(g) The Sectional Committees shall meet not later than the first day of the Session in the Rooms of their respective Sections, and prepare the programme for their Sections and forward the same to the General Secretaries for publication.

(h) The Council cannot guarantee the insertion of any Report, Paper, or Abstract in the Annual Volume, unless it be handed to the Secretary before the conclusion of the Session.

(i) The Sectional Committees shall report to the Council what Reports, Papers, or Abstracts it is thought advisable to print, but the final decision shall rest with the Council.

## XV.—RESEARCH COMMITTEES.

(a) In recommending the appointment of Research Committees, all members of such Committees shall be named, and one of them, who has notified his willingness to accept the office, shall be appointed to act as Secretary. The number of Members appointed to serve on a Research Committee shall be as small as is consistent with its efficient working. Individuals may be recommended to make reports.

(b) All recommendations adopted by Sectional Committees shall be forwarded without delay to the Council for consideration and decision.

#### XVI.—ALTERATION TO RULES.

Any proposed alteration of the Rules

- (a) Shall be intimated to the Council Six Months before the next Session of the Association,
- (b) Shall be duly considered by the Council,
- (c) And, if approved, shall be communicated by Circular to the Members of Association for their consideration,
- (d) And dealt with at the said Session of the Association.

#### XVII.—VOTING.

In Voting for Members of Council, or on questions connected with Alterations to Rules, absent Members may record their vote in writing.

---

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## ADDRESS.

By SIR DAVID GILL, K.C.B., LL.D., F.R.S., HON. F.R.S.E.,  
President.

It gives me much pleasure, as President, to welcome the large number of Members and Associates of the South African Association for the Advancement of Science who have assembled here to-night.

Our history up to the present time is a very brief one. On the 2nd of July, 1901, a meeting was held under the presidency of Sir Charles Metcalfe with a view to arrange for an Annual Congress of Engineers. It was felt that as there are many men throughout South Africa who are engaged in work connected with applied Science, they would do well to arrange an annual opportunity of meeting together in order to compare notes and to derive from mutual intercourse that stimulus to thought which can only be acquired by personal intercourse, or, in a more detailed way, by the reading and discussion of technical papers.

At the meeting in question a preliminary resolution was proposed by Mr. T. Reunert, and finally carried unanimously, viz.:

"That this meeting approves of the proposal to hold an Annual Engineering Congress in South Africa."

In the discussion which followed, questions were raised as to the exact meaning to be attached to the word "Engineering," and it was agreed, for the time being, to accept the definition of the Institute of Civil Engineers, viz.: "The art of directing the great sources of power in Nature for the use and convenience of Man." At the same time the whole subject both as to the nature and scope of the Congress was left open for further consideration, and a Committee was appointed (with power to add to their number) for the purpose of framing a Constitution to be submitted to the first Annual Congress.

Even at this first meeting there was a tendency to define the term "Engineer" in a very wide sense, and to embrace within the list of members of the proposed Congress not only those engaged in the utilization of Science, but those also whose lives and interests are occupied in the pursuit of Science for its own sake.

The first meeting of the Committee was held on Tuesday, the 9th July, 1901, and its first object was naturally to define more precisely the exact scope, form and objects of the proposed Congress. The opening discussion shewed plainly enough that, in the minds of those

present, the various views of the originators of the proposed Congress, as well as those of the other members of the Committee, could be best brought into accord by the formation of an Association—some-what on the lines of the British Association—meeting once a year, now at one centre of South Africa now at another, and its work should be divided into sections devoted to different subjects. Thus, whilst those interested in any particular department of Science could give attendance chiefly to their own special section, all would have an opportunity of meeting socially and enjoying that advantage of interchange of ideas which is so helpful to general scientific progress.

Finally, on the 12th September, 1901, a general meeting was held in the Hall of the Education Department, Cape Town, at which the following resolution was passed:

“That this meeting approves, and hereby confirms, the formation of a South African Association for the Advancement of Science, as far as possible on the lines of the British Association.”

A Committee was appointed to draw up a draft constitution, and the results of its finally revised and approved labours are in the hands of members.

When in London in 1900, I was requested to attend a meeting of Council of the British Association for the purpose of discussing the possibility of holding one of their meetings in South Africa. It had seemed to the founders of our new Society that to bring about such a visit would in itself be a great object. Accordingly, so soon as peace was declared, steps were taken to ascertain the earliest date for which an invitation from the Cape could be entertained. It appeared that the arrangements for the meetings of the British Association had been made as far as 1904 inclusive, and we now know that the meeting for that year will be held at Cambridge under the Presidency of the Right Hon. Arthur Balfour, Prime Minister of England.

On approaching Sir Gordon Sprigg as to what facilities could be offered to induce the British Association to accept an invitation to visit the Cape in 1905, I received in reply the following sympathetic and encouraging letter:

Prime Minister's Office.

Cape Town,

16th August, 1902.

Sir,—

I have submitted to the Prime Minister your letter of the 15th instant, addressed to me, with reference to the proposed invitation to the British Association to visit South Africa in 1905, and I am directed to inform you in reply that the Cape Government agrees as follows, viz. :—

1. That free railway passes be granted over the Cape Railway system for all officials of the British Association and a limited number of invited guests.

2. That a sum not exceeding £6,000 be guaranteed towards the cost of passages to and from the Cape for the above-mentioned officials and visitors. This amount to be shared by the Governments of the Transvaal, Natal, and the Cape.

I have, etc.,

(Signed) HENRY DE SMIDT,  
Acting Secretary to the Prime Minister.

Sir David Gill,  
H.M. Astronomer.

The other Governments have undertaken to share the half of this responsibility, and to grant similar free use of their railways. I am assured that there will be no lack of private hospitality, and, as you are all now probably aware, the Council of the British Association, on the 6th of March, unanimously resolved to recommend to the General Committee of the Association at the Southport Meeting next September that the invitation to hold the Annual Meeting in 1905 in South Africa be accepted.

This much for our history up to the present moment, and so far as it goes it is a very gratifying one.

We have at the present time a roll of 702 ordinary members and 36 associates. In point of numbers this compares favourably with the beginnings of the British Association, which at its first meeting at York in 1831 had 353 members—numbers which, however, in the following year at Oxford increased to 435 members.

One cannot, of course, compare in weight of scientific importance the present meeting with those at York and Oxford on the occasions in question. But, if we consider how comparatively small is the white population of South Africa, how great are the distances which separate it, we may at least congratulate ourselves on the fact that there have been found so many ready to take a sympathetic interest in the objects of the Association, and so large a proportion of men who have come forward to contribute papers of scientific interest and practical value.

With such encouragement let us consider carefully in what way the interest thus aroused may be turned to the best account for the promotion of Science and the welfare and progress of this country.

My first duty is to lay before you the claims of Science to the sympathy and support of every citizen and every Government of a civilized community.

Persons gifted by nature with the capacity for original scientific research of high value are comparatively few in number—much in the same degree that the number of original poets, musicians, painters and sculptors is also limited.

The world has long recognised the value of art and literature as refining and elevating influences. But, for one who can lay claim to the creation of classic work in literature, music, painting or sculpture, there are thousands with minor claims to originality in

these subjects, and tens of thousands with sufficient knowledge to raise the plane of their aspirations, to unite them in bonds of sympathy with others of like tastes, and thus to brighten their enjoyment of life.

Nay, more than this, there is no ordinary thinker or worker in any of these fields who may not at some time contribute an original idea, which, in the hands of genius, may later be fashioned into the great and beautiful.

If these things be true of Literature and Art how much more are they so in regard to Science. To the Colonist Science appeals, or should appeal, with a double force. It is not only a source of intellectual elevation and a high form of enjoyment to all who sufficiently interest themselves in its pursuit, but it also lies at the foundation of our civilization, and even of our existence. To it we owe conveniences, comforts, and the possibility of activities which have insensibly become to us the necessities of life; and more than this, it is not too much to say that, without the advantages of defence and inter-communication given to us by the applications of Science, the very existence of a scattered white population in South Africa would be impossible; and it is mainly to the applications of Science that we must look for the development of those natural resources with which this Sub-Continent has been so abundantly endowed.

There is a type of self-called practical man who forgets these things. He adopts the results and methods of Science, but too often cares and knows nothing of the processes by which these results have been obtained or the principles which underlie their attainment. Do you understand the electric telegraph? "Oh, yes! You have only to write your message, give it to the man at the counter, and pay a shilling." That, really, with little exaggeration, is typical of the attitude of mind to which I refer, and with which too many people regard the thousand amenities that Science has brought into modern life.

Too often indeed there is an assumed antagonism in many minds between Science and Commerce—or, as others put it, between theory and practice.

Bear, however, this in mind, that between true theory and true practice there never can be any discordance. The laws of Nature do not change in capricious ways, and, therefore, in regard to any mechanical or natural process about which the laws and facts are absolutely known, the results of theory and practice must coincide.

By what process, then, can we attain to true theory? I cannot put the matter better than in the words of Dr. Whewell in an address delivered by him before the meeting of the British Association held at Cambridge in 1833. He said:

"Without attempting any nice or technical distinctions between theory and hypothesis, it may be sufficient to observe that all deductions from theory for any other purpose than that of comparison with observation are frivolous and useless exercises of ingenuity, so far as the interests of physical science are concerned. Speculators, if of active and inventive minds, will

form theories whether we wish it or no. These theories may be useful or they may be otherwise—we have examples of both results. If the theories merely stimulate the examination of facts, and are modified as and when the facts suggest modification, they may be erroneous, but they will still be beneficial; they may die, but they will not have lived in vain. If, on the other hand, our theory be supposed to have a truth of a superior kind to the facts, to be certain independently of its exemplification in particular cases; if, when exceptions to our propositions occur, instead of modifying our theory we explain away the facts, our theory then becomes our tyrant, and all who work under its bidding do the work of slaves, they themselves deriving no benefit from the results of their labours."

This seems to me one of the most thoughtful and best expressed summaries of the proper scientific use of the imagination with which I am acquainted, and it indicates the slow and gradual process by which alone the laws of Nature can be traced.

Take, for example, the history of Newton's discovery of the law of gravitation.

About the year 1666, Newton began to turn his attention to the consideration of the force which we now call gravity. In that year, according to the well-known story, he was one day sitting in a garden when he saw an apple fall to the ground, and came to the conclusion that such a phenomenon could only be the result of the Earth's attraction. Then it immediately flashed upon him, if the Earth attracts the apple so that when, by decay, the stalk becomes sufficiently weak, the apple is pulled to the ground, why should not this same force of attraction extend from the Earth to the Moon?

Here the popular story stops, and it is inferred that Newton, then and there, made his immortal discovery; but in reality it is just here that the truest interest of the story begins.

The idea of an attractive force like gravity was no new one. Kepler, in his "*De Stella Martis*," states that every two bodies of the same kind have the property of attracting each other—thus the Earth attracts a stone and the stone attracts the Earth, but the attraction of the Earth is much greater than that of the single stone in the proportion of the much greater quantity of matter which it contains. Kepler had discussed the numerous planetary observations of Tycho Brahe, and from these and his own observations had discovered his three now well-known laws of planetary motion; but, apparently, from assuming that the gravitational attractive force between two bodies must vary in direct proportion to the distance between them, he missed the great generalization which it was left to Newton to discover.

Newton, of course, knew that the intensity of the illumination of a surface from a point of light varies inversely as the square of the distance of that surface from the source of illumination.

Reasoning by analogy, it seems probable that Newton would imagine that the force of attraction between two bodies would vary according to the same law, and he worked out a rigid mathematical

proof demonstrating that if the planets move according to Kepler's laws they must move under the influence of a force directed towards the Sun and varying inversely as the square of the distance from the Sun.

Having obtained this law, Newton sought to verify it, and to ascertain whether the attractive force of the Earth is similar in kind to that of the Sun, and whether, therefore, the Moon moves round the Earth in obedience to the same law. He had first to prove, and with some difficulty and delay did prove mathematically, that the attraction of a globe is the same as if its matter were all concentrated at its centre. This done, he obtained a measure of the attractive force of the Earth at a distance from its centre equal to its radius, by determining experimentally that any heavy body near the Earth's surface dropped from a height would fall from rest about 16 feet in the first second of time; or, if the law of inverse squares were true, the amount of fall would increase as the square of the time, so that the fall of a heavy body near the Earth's surface in 60 seconds would be  $60^2$ , or 3,600 times 16 feet.

In Newton's time it was fairly well known that the mean distance of the Moon from the Earth is approximately 60 radii of the Earth. Therefore the force of the Earth's attraction on the Moon would be  $1/60^2$  or  $1/3600$  part of that which it exerts on a body near the Earth's surface. In other words, the Moon would fall towards the Earth just as far in a *minute* of time as a stone near the Earth's surface would fall in a *second* of time—that is to say, 16 feet.

Newton next compared this hypothetical fall of the Moon towards the Earth in a minute of time with the actual deflection of the Moon's orbit from a straight line in the same unit of time. With the data at his disposal he found the computed actual fall to be 13 feet instead of 16 feet, as he had determined that it should be if his hypothesis was correct.

Newton regarded this discrepancy as so fatal that, in his own words, he "laid aside at that time any further thought about the matter."

In 1672 the result of Picard's new measurement of an Arc of Meridian in France was communicated to the Royal Society, and it shewed that the length of a degree, instead of being 60 miles as Newton had accepted it to be, was in fact  $69 \frac{1}{8}$  miles. Newton does not appear to have known of Picard's result until his attention was called to it by a letter from Hooke in 1679, and then Newton at once realized its important influence on his original conclusions. His previous unit of measure for the dimensions of the Moon's orbit, and therefore for the actual fall of the Moon towards the Earth in a minute of time, was erroneous by 16 per cent. It is said that Newton was so excited when making the comparatively simple calculation required to ascertain the effect of the new data upon his original conclusions, that he was unable to complete it, and had to ask a friend to do it for him. The result shewed that, with the new data, the actual fall of the Moon towards the Earth in a minute of time was 16 feet per minute, agreeing exactly with the amount calculated

from the known distance of the Moon in terms of the Earth's radius and the rate of fall of heavy objects at the Earth's surface.

Still, Newton's work was not yet done—in fact in this matter it was only begun. He had not only to conceive all the possible consequences of the existence of his law of gravity but to invent the mathematical processes by which these consequences had to be traced. It was only by the combination of the most supreme genius both as a physicist and mathematician, coupled with the severest abstraction of thought from any subject but the one in contemplation, that such results could be reached; or, as he himself puts it, "I keep the subject constantly before me till the first dawnings open slowly by little and little into a full and clear light."

The years of 1685 and 1686 will ever be memorable in the history of Science, as in them was produced Newton's *Principia*, of which it is no exaggeration to say that it is the greatest intellectual effort ever achieved by man.

It is a noteworthy fact that Newton's *Principia*, which appeared in 1687, was not printed at the cost of the Royal Society, but actually at the private cost of his friend Halley, because that learned but then impecunious body, the Royal Society, had exhausted its resources in the publication of a *History of Fishes* by a Mr. Willoghby!

Some apology is due for introducing in an address like the present so old and oft repeated a story as the history of the discovery of the law of gravitation. My only excuse is that I know of none other which illustrates so completely the points on which I desire to insist.

First of all, note the long laborious process and the efforts of many men and many minds by which alone knowledge of any law of Nature can be evolved and established, and how great scientific discoveries, like coming events, cast their shadows before.

Leonardo da Vinci, a hundred and fifty years before Newton, and later, Galileo and Huygens, all had glimpses of the action of some force like gravity, and wrote about and discussed its existence; Kepler had the matter almost in his grasp, and probably, but for a preconceived hypothesis that an attractive force must vary as the distance, would have discovered it, although he was not mathematician enough to trace out its consequences. Tycho Brahe, 100 years before Newton, began the series of observations of the planets which he and Kepler continued for 50 years, when the latter derived from their discussion his laws of planetary motion—the primary key to Newton's discovery.

Note also Newton's true philosophic spirit. There was no attempt on his part to claim for his hypothesis "a truth of a superior kind to the facts," or to explain away facts, as he might have done in view of the then uncertain determination of the dimensions of the Earth. He waited 11 years for improved facts, and then devoted 7 years to the completion of his *Principia*—the irrefragable proof of the truth of his theory.

If we may trust the story of the fallen apple—and it rests on the authority of Voltaire—note the importance of reflexion upon and study of the origin of the most simple and ordinary phenomena, and of the value of suggestion from every source. The history of Newton's life shews how much even he was indebted to the suggestion and incentive of his few scientific contemporaries.

Above all, note his recognition of Man's intellectual limitations. Newton realised that he had discovered a great law of Nature, and that, by means of this discovery coupled with observation over a comparatively short period, the motions of the heavenly bodies could be traced out in all past and future time; but he felt himself intellectually powerless in face of the question: "By what method does this action at a distance take place?"

"I know not," said he, "what the World will think of my labours, but to myself it seems to me that I have been but as a child playing on the seashore; now finding some pebble rather more polished, and now some shell rather more agreeably variegated than another, while the immense ocean of truth extended itself unexplored before me."

We find a like key-note in the words used by the greatest living scientist of our day—I mean by Lord Kelvin—on the occasion of the celebration of the Jubilee of his Professoriate at Glasgow in 1896: "One word characterises the most strenuous of the efforts for the advancement of Science that I have made perseveringly during fifty-five years; that word is failure. I know no more of electric and magnetic force or of the relation between ether, electricity and ponderable matter, or of chemical affinity than I knew and tried to teach my students 50 years ago in my first session as a Professor. Something of sadness must come of failure; but in the pursuit of Science, inborn necessity to make the effort brings with it much of the *certaminis gaudia*, and saves the naturalist from being wholly miserable, perhaps even allows him to be fairly happy, in his daily work.

"And what splendid compensation for philosophical failures we have had in the admirable discoveries by observation and experiment on the properties of matter and in the exquisitely beneficent applications of Science to the use of mankind with which these fifty years have so abounded."

What are we to derive from these and like expressions of our greatest masters—certainly not discouragement, for the great ocean of truth still remains open for exploration.

But are there not limitations which we may never hope to pass? Are the possibilities of scientific knowledge really divisible into the knowable and the unknowable?

One may perhaps venture on a conjecture, viz., that *the limit of the KNOWABLE is a complete mastery of the laws according to which the great agencies of Nature work, but that these agencies themselves are the UNKNOWABLE.*

The conjecture is at least justified by experience, although I fear it verges dangerously on the shoals of philosophy.

It is not wise to attempt to define too closely the borderland of profitable scientific activity, for one cannot forget that about 60 years ago the French Philosopher Comte, in his *Cours de Philosophie Positive*, quoted the chemical constitution of the Sun and Stars as an example of the Unknowable, a statement the fallacy of which was proved by the subsequent results of Spectrum Analysis.

And yet the greatest of scientific men have at times forgotten the futility of Aristotelian methods and been drawn aside by some irresistible attraction from the strait and narrow paths of the Baconian method.

I may perhaps be allowed to quote an interesting instance within my own experience.

Some 20 years ago, in the old smoking-room of the Athenæum, I was talking with Professor Huxley about the rising scientific men in England, when he brought up the name of my late dear friend George Romanes. "Now," said Huxley, "there is a man that I regard as the ablest of the young men in my line of work; but of late he has taken to philosophy, and it is all up with a man of Science when he does that." Some years later George Romanes founded the Romanes Lectureship at Oxford. The idea of the foundation was to obtain every year from some distinguished man, towards the close of his career, a lecture which should, as far as possible, represent the outcome of his experience and knowledge. At the end of 10 years the lectures were to be printed and published in a volume, which might thus be expected to contain the best thoughts of the decade. Gladstone was the first Romanes-lecturer, Huxley was the second. Not very long after the delivery of his lecture I again met Huxley in the same place and reminded him of our earlier conversation, asking how it was that, after censuring Romanes so severely for dabbling in philosophy, his own Romanes lecture was only philosophy of the deepest dye. "Ah, yes," he replied with a smile, "I suppose it is the decadence of old age."

Pure Mathematics is the only Science which, if its original postulates and definitions are granted, is independent of comparison with external nature, and it might have been developed from them alone to its present stage, or further, by generations of men who never saw the earth or sky. Carping philosophers may gird at the sufficiency of its axioms and definitions, but these axioms and definitions are self-evident to common-sense, and no part of the superstructure logically raised on them has ever departed a hair's breadth from the truth under any stress to which, during the centuries since Pythagoras, it has been exposed.

A supreme point to be impressed on every worker in Science is the cultivation of the most rigorous accuracy of thought, work and expression. In the sciences of observation too much stress cannot be laid upon the necessity of accepting for fact only that which is really fact. This, on the face of it, seems a needless statement. But in the determination of any fact which depends on measurement or estimation by human agency there must remain an outstanding uncertainty which may be great or small according to the skill

of the observer, and the precision of his tools and methods. A determination is only exact—its result only a true fact—when all the possible sources of error which can possibly affect it, have been carefully computed and estimated, and the uncertainty of the result, as well as the result itself, are stated. The value of a result, as a published addition to Science, will very much depend on the clearness of the statement as to the precautions which have been taken for elimination of systematic errors and the completeness of the deduction of its probable or its possible error due to sources of all kinds—systematic and accidental.

We may safely state that it is largely to the increased attention paid to this necessary feature in the conduct and publication of researches that we owe much of the scientific advance of the past 25 years.

Were this a purely Physical, Chemical, Astronomical or Geodetic Association, one would be tempted to dwell on this subject for the remainder of the Address, and to illustrate by examples the fuller significance of these remarks; but as there are many other subjects which it seems desirable to touch, it must suffice to quote Lord Kelvin's words of over 30 years ago, viz.:

"Accurate and minute measurement seems to the non-scientific imagination a less lofty and dignified work than looking for something new. But nearly all the grandest discoveries of science have been the rewards of accurate measurement and patient, long-continued labour in the minute sifting of numerical results."

That is undoubtedly true of Astronomy, Chemistry and Physics.—I believe it to be increasingly true of Geology and Physiology, and probably also of other sciences.

Turning now from the duties of the Scientist to Science, let us consider briefly the duties of our Association to Scientists and to other Scientific bodies.

The objects of our Association are defined by our Constitution as follows:

"To give a stronger impulse and a more systematic direction to Scientific enquiry; to promote the intercourse of Societies and Individuals interested in Science in different parts of South Africa; to obtain a more general attention to the objects of pure and applied Science, and the removal of any disadvantages of a public kind which may impede its progress."

This definition is, as nearly as possible, identical with that adopted by the British Association, and it has proved to be a sound and satisfactory basis for the work carried on by that body with so much success for more than 70 years.

You will observe that we use the words to promote "the intercourse of Societies and individuals interested in Science," instead of "the intercourse of those who cultivate Science," and this alteration was advisedly introduced on two accounts.

In the first place we think it the more accurate description of our own possibilities, and, if I may venture to say so, it is also a

more complete description of the actual practice of the British Association.

In the second place we wish to emphasise the fact that the last thing which this Association desires to do is to interfere with the existence or function of any existing Society.

Some misunderstanding has arisen on this point, an idea that this Association was to usurp all the scientific functions of the country—to absorb all the other Societies in itself, to have active branches in all parts of South Africa, each of them with frequent meetings and popular lectures given by lecturers supplied by the Association—and I know not what besides. In fact we were to combine in ourselves not only the functions performed in England by the British Association, but also those of the Royal Society, of the whole of the metropolitan and local Scientific Societies, of the University Extension Lectures, and of the sensational popular lecturer as well. Even if this were possible on an Annual Subscription of £1—which it is needless to say it is not—it would be hard to conceive any plan more likely to discourage working Scientists and to do more harm to scientific progress in this country.

Take, for example, the South African Philosophical Society, which in spite of much neglect and discouragement after its foundation by Sir Bartle Frere, has fought a good fight for 25 years and won for itself a recognized position amongst the Scientific Societies of the world by publishing regular transactions containing some papers of classic value; and it has also acquired by exchange and purchase a valuable scientific library of reference.

Is it reasonable to suppose that such a Society and its followers in other parts of Africa are to extinguish themselves because this Association has come into being? Certainly not. The hard work of original research and its presentation, discussion and regular publication are the business of these Societies. That important work should go on quietly at their regular meetings, and we believe it will do so with increased efficiency in future, not *in spite of* but partly *because* of the very existence of this Association.

But to return to the "Objects of our Association." You may note that we describe the field of our operations as that of promoting intercourse "in different parts of Africa" instead of the more ambitious field "the British Empire and foreign philosophers."

These modifications of ours appear to be justified. We can hardly—not yet at least—expect to attract many foreign philosophers to our shores for the sake of this Association alone, although we do expect to help in a humble but effective way in bringing the parent Association here, and with it not a few foreign Scientists in its train, as well as many more from the Old Country and from all parts of the British Empire. (I may perhaps be allowed here to add parenthetically that I have heard from Lord Kelvin to the effect that although he does not forget that in 1905 he would be 81 years of age, yet, if he is as well then as he is now, nothing would give him greater pleasure than to visit us at the Observatory and attend

the Meeting of the British Association in South Africa in that year.)

It cannot be without a lasting beneficial influence on the intellectual and material progress of the country that a body of men, distinguished in every branch of pure and applied Science, should come to this country, meet us in social and scientific intercourse, examine for themselves the resources of the country and the great social and scientific problems which call for solution. That, I think, goes without saying. But we venture to hope also that out of such a visit must arise a deeper common interest, a wider mutual view, a larger sympathy even than that which exists at present, and which already binds Britain and her Colonies together by so strong a tie.

I feel sure that every one here to-night, every member of the Association, all who have the best interests of the country at heart, will unite in giving to our visitors our warmest hospitality and welcome, that they may carry back with them not only memories of an interesting visit, but of true and warm hearted friends that they have found in South Africa.

One of our chief functions is to bring together once a year (now at one centre in South Africa, now in another), not only the working members of the various Scientific Societies throughout the country, but all who are interested in Science either in an active or sympathetic sense.

There are many with undefined scientific tastes or with very modest appreciation of their own possible usefulness, who hesitate to join the more formal societies, but who feel that they may join such an association as this. I know not a few who, in attending a meeting of the British Association, have found such sympathy, such help, such interest as the result, and who have developed such unexpected capacity of their own that they have subsequently themselves become active workers in Science.

Speaking from my own experience, I have a boyish recollection of the meeting of the British Association at Aberdeen in 1859, with Prince Albert in the chair, but beyond an excited general interest in the whole affair I can remember no special benefit I derived from it. The next at which I was present was the meeting at Edinburgh in 1871.

Lord Kelvin (then Sir William Thomson) was in the chair. I was very keen about a little bit of practical astronomical work of my own from which I attempted to draw an important conclusion. It was a very bad bit of work, and its conclusions were all wrong; but I was treated with a kindness and consideration which my work did not deserve. I received useful hints and suggestions, and had instilled into me some of those principles of scientific caution which I have already tried to preach to you. I met men for the first time whom I have since had the privilege of regarding as amongst my best and dearest friends, and without whose help, encouragement and guidance I could never have accomplished even the little which I have since been enabled to do in the way of useful work for Science.

Believe me, there is no more important function of an Association like this than the opportunity which it offers for suggestion, guidance, and the formation of scientific friendship. I hope, in the days to come, that there will be not a few who are able to speak from experience in like terms of the benefits of this Association.

The advances of Science during the past century have been so rapid that none but a specialist in a limited department can hope to follow all the work done, as it appears in the original communications. But the British Association has stepped in and provided its "Reports on the State of Science"; these are invaluable to the general scientist, and they afford even to the specialist a comprehensive glance of his subject, an invaluable source of reference.

There are two promised communications in our Agenda which may be quoted as types. I refer, on the side of pure Science, to Dr. Muir's paper, entitled, "A Third List of Writings on Determinants." In this department of Mathematics, Dr. Muir is probably the leading authority. The work in question completes the extensive bibliography of the subject of which two parts have already been published by him.

On the side of Applied Science I refer to Mr. Caldecott's communication on "The Cyanide Process from its Introduction into the Rand to the Present Day."

Both these papers, and many others in the list of our Agenda, are types of reports peculiarly suited for communication to such an Association as ours. They are not mainly the results of original investigations on the part of their authors, and, therefore, as such they come less distinctly within the field of a body like our Philosophical Society, but they are precisely the sort of thing which it is the province of this Association to cultivate and to publish as reports. In their respective subjects they are condensed archives to which either the specialist or the more general scientist would turn as a first aid to further investigation or knowledge.

There is a third function of our Association which is no less important if we are to follow the example of the British Association—I mean the "grants to committees and individuals for scientific purposes" which have been voted by that body from the third year after its inception. The first step in this direction was made in 1834, when a modest sum of £20 was voted in aid of tidal discussions. This rose to £157 the following year, to £435 in 1836, and to £922 in 1837, since which time the vote has generally exceeded £1,000 a year. The total amount expended by the Association in this way to the present time amounts to nearly £70,000.

The principal cities of the United Kingdom emulate one another in the cordiality of their invitations for the Association to become their guests, and sometimes deputations with the Mayor and some of the Councillors attend a meeting to urge officially the acceptance of their hospitality. Doubtless the blandishments of various Municipal Corporations will be exercised this year at Southport to induce the British Association to visit their respective cities

in 1905, but I have great confidence that the unanimous decision of its Council taken seven weeks ago will prevail, viz., to recommend the meeting at Southport in September next to accept the South African invitation.

We unquestionably owe to Sir Gordon Sprigg and to the representatives of the other Governments of South Africa our warmest thanks for the hearty and substantial manner in which they have backed this invitation.

It is the practice for the local authorities to make arrangements to defray a large part of the expenses of the meeting, to entertain by private hospitality its office-bearers and specially invited distinguished men, and to provide the whole of the expenses of the various general entertainments, so that the income of the British Association is free to be spent upon its scientific objects.

Here in Cape Town we gratefully acknowledge the hospitality of the Mayor at this first meeting of our South African Association. Your programmes will inform you how generous that hospitality is.

No attempts have been made to solicit local subscriptions, so that the funds available for the use of our Association arise entirely from the entrance fees of Members and Associates.

Within the past few days, Sir Gordon Sprigg has informed me that the Government of the Cape Colony has undertaken the cost of printing the Reports and Papers of this Meeting. This sympathetic and generous action on the part of Government will allow the whole of the assets of the Association to be available for the cost of secretarial work and grants in aid of scientific research.

This being so, every citizen who has joined our Association will have the satisfaction of knowing that, even if he or she has made no researches in Science, they have at least contributed something in sympathy and aid for its advancement.

Looking to the future prospects of scientific progress in South Africa, I believe there is sound reason for the statement that these prospects are very hopeful, and the present a peculiarly suitable time for the inauguration of such an Association as this.

The nucleus of active original work in Science must in any community centre round the comparatively small number of men whose lives are professionally devoted to its pursuit. Far be it from me to deprecate the efforts of the so-called amateur. In the true sense of the word every professional scientist should be an amateur, for if he does not *love* his work he is certain to be a miserably inefficient creature. In young countries, where most men find their daily bread by their daily work, the number of those who have the capacity, and at the same time can afford to add the active cultivation of Science to their daily pursuits, is necessarily more limited than in countries where means and leisure are more abundant.

All the more honour to those who, like Roberts of Lovedale in Astronomy, or Bolus of Cape Town in Botany, have done, and are doing, work for Science which any professional astronomer or botanist might well envy. It is a hopeful sign for us that the Cape

University has conferred on these men the honorary degree of Doctor of Science, the highest recognition of their labours which it is in its power to bestow.

Fully, therefore, as one recognises the invaluable work of men like Roberts and Bolus, and the still more invaluable example which they give, it is impossible to overlook the fact that it must be mainly on the professional scientist that we have to rely for the increase of our workers in the higher departments of research.

Reference to the papers in the Philosophical Transactions of the Royal Society and the like will shew that even in the United Kingdom this is the case.

It is, therefore, a most hopeful sign of progress that the South African College has of late made a great stride by way of strengthening its staff. Within the past few months there have been added Chairs of Zoology, Botany, and History. The departments of Mathematics and Chemistry have been strengthened by additional assistants. A Chair of Engineering is about to be created, and the subjects of Logic and English Literature, formerly in the hands of one Professor, are now divided into two Chairs.

Steps are being taken at the Victoria College, Stellenbosch, with a view to the creation of a new Chair in Zoology, and a separate Chair of Geology (instead of connecting the latter as at present with Chemistry); it is also proposed to raise the Lectureship in Botany to a full Professorship. Of St. Andrew's College at Graham's Town one hears that there is a possibility of its being remodelled into a University-College that will provide for efficient higher Science teaching in the Eastern Province.

In addition to the Professors of University Colleges we have as professional scientific men in the Cape Colony the officers of the Museums, of the Geological Survey, and of the Bacteriological Institute, the Government Biologist with his Trawler and Marine Laboratory, the Government Botanist, the Entomologist, the Analyst, the Secretary of the Meteorological Commission, the Conservator of Forests, and the Chief Government Veterinary Surgeon.

In the Transvaal we have the Departments of the Ordnance Survey, the Geological Survey, of the Museum and Zoological Garden, of the Government Analyst, the Government Bacteriologist, the Director of the Meteorological Department, and corresponding officers of similar but less numerous departments in Natal, the Orange River Colony, and Rhodesia.

Many of these men and the officers of their staffs are doing good original scientific work—*all* of them should do it.

I am unable to enumerate the many who are engaged in the utilization of Science as in railway construction, mechanical engineering, and in the design and erection of large machinery for waterworks, irrigation works, works for electric lighting and electric power transmission, rock-drilling, water-boring, hoists, and all the appliances connected with large mining operations. The rapidly growing discoveries of mineral wealth point to an immense industrial development in the near future.

We have, foreshadowed, the utilization of the Zambesi Falls and the electric transmission of such part of their immense energy as is necessary for working the great coal, iron, copper, and gold mines which lie inside a radius that is well within the limit of economic working by use of high tension currents.

With cheap power thus available, with excellent coal and good iron ore, it will probably be possible to manufacture economically in Rhodesia all the steel rails required for present and future use in South Africa, and to compete successfully with the Home market in the manufacture of corrugated iron, wire fencing, and other articles of the kind for which there is so large a demand in this part of the world.

But it is not my immediate object to enter into the possibilities of the economic development of South Africa, but rather to point out that for such development the services of a very large body of able scientific men will be required.

If her own sons are to take their part in this great development, South Africa is bound to provide for their thorough education and training. And, along with that education and training of young and eager minds, she will, if the work is properly done, not only advance her material interests, but raise the intellectual level of the rising generation, and contribute her share in the World's Advancement of Science.

In the selection of Professors for this end we must be careful to appoint only men of the right type.

The mere utilization or teaching of Science is not scientific activity. In Science, as in everything else, there is no such thing as standing still. You must advance or go backwards. In the earlier stages of scientific study it is true that the foundations may be laid, and often are very soundly laid, by a teacher who teaches little more than what is to be found in the text-books, but I imagine that the fire of the original thinker and worker must be in the heart of every successful teacher even of elementary Science although he may lack time and opportunity for its pursuit.

In the higher departments of scientific teaching the spirit of the work is missed, its whole essence as a mental development lost, if the Professor himself has not the inborn spirit and the time and opportunity for original research.

Time was when the attempt was made to teach Physics and Chemistry without working laboratories, and with the mere exhibition on the lecture-table of routine apparatus and class experiments. I remember these conditions only too well. The hopeless inefficiency and "dry as dust" character of such a method of teaching experimental Science is now so well understood that I need not further condemn it.

Although it is now admitted that laboratory work is essential even in moderately elementary teaching of experimental Science, it is not yet fully realized how much greater is the value of the work of a teacher in every branch of Science who is himself also an original thinker and worker.

In the higher departments of all kinds of scientific training it is not too much to say that the capacity for and the practice of original research on the part of the Professor is *essential* for the creation of a vigorous school of thought and healthy aspiration on part of the students. This view was well stated by Sir Michael Foster in his Presidential Address to Section I. at the Toronto Meeting of the British Association in 1897. He said:

"Now each teacher, however modest his post, feels and says that the authorities under whom he works are bound to provide him with the means of leading his students along the only path by which Science can be truly entered upon, that by which each learner repeats for himself the fundamental observations on which the Science is based.

"But there is a still larger outcome from the professorial chair than the training of the students; these are opportunities not for training only, but also for research. And perhaps in no respect has the development during the past thirteen years been so marked as this. Never so clearly as during this period has it become recognized that each post for teaching is no less a post for learning, that amongst academic duties the making knowledge is as urgent as the distributing it, and that among professorial qualifications the gift of garnering in new truths is at least as needful as facility in the didactic exposition of old ones."

Although these words were spoken more especially in connection with the teaching of Physiology, they hold to the full as true with respect to all the experimental sciences; and in connection with the teaching equipment of our Colleges one can hardly insist too strongly on their importance.

To increase the number of Chairs is certainly a desirable object; but it is even still more necessary to find the right kind of Professor, and provide him with assistance in amount and quality sufficient to allow him reasonable leisure for research.

The Professor who has not that opportunity, whose hours of teaching alone make up nearly the hours of a schoolmaster's duty, is practically debarred from research, and his teaching, unless he is a man of exceptional energy and strength of constitution, is sure to lapse into dull routine and to lose all that fire and interest which the pursuit of original thought and research can alone give to it.

It is eminently satisfactory to find that, in connection with the new Chairs of Botany and Zoology at the South African College it is expressly stated, that, as the number of classes in each subject will be comparatively small, original research will be regarded as part of the Professor's duties.

The South African College has been congratulated on obtaining able men to fill these Chairs notwithstanding the modest salaries it was able to offer; no doubt the temptation offered by opportunity for research was the real secret of that success. There is no man worth his salt who would not regard such a position as preferable to one more highly paid but without that opportunity. If our

Colleges want good Science Professors they now know the true way to get them. By these remarks I do not imply that a good Professor should be badly paid, but that amongst the temptations which induce the best men to come forward none can be greater than the acknowledgment that original research will be regarded as an important part of their duty, and that time and opportunity will be given for this purpose.

It was my intention, as part of this address, to present a short account of the work that has been already done for Science in South Africa, and which, with the assistance of some of our members, was prepared for this purpose. The limits imposed by time render it necessary to relegate these remarks to the lot of "papers taken as read."

It is impossible, however, to refrain from mention of one particular work now in progress which is not only of great scientific and practical value, but the mode of its inception and execution marks the kind of spirit we wish to find in the Professors of our University Colleges and in those who are responsible for the government of the country. I refer to the Magnetic Survey of South Africa.

This Survey was started in December, 1897, by Professors Beattie and Morrison, entirely at their own cost and carried on during their vacations. The work was continued by them during the College vacations of subsequent years with the aid of grants, partly from the Government Grant Fund of the Royal Society of London, partly from the Government of the Cape Colony. In August of last year a proposal was made by Dr. Beattie to devote the whole of the year 1903, and till February, 1904, to the work, if the necessarily heavy expenses could be provided. This offer became possible from the fact that the terms of Dr. Beattie's engagement provided for a year's leave after five year's service, if a suitable temporary substitute was supplied. Dr. Beattie's work has a special importance during the present year because it fills a gap which would otherwise exist in the series of magnetic observations now being made in other parts of the world simultaneously with those which are now being carried out by the Antarctic Expeditions near the Southern Magnetic Pole.

His Excellency Sir Walter Hely-Hutchinson, recognizing the importance of the work and the self-sacrifice and devotion which prompted it from the beginning, interested himself in procuring the necessary funds. Thanks to him and the generosity with which the various Governments of South Africa responded to His Excellency's appeal, Dr. Beattie is now free to devote himself wholly to the work until February, 1904, by which time, if all goes well, it will be completed.

I venture, in His Excellency's presence, to express the thanks of all who are interested in the progress of Science for his ready aid in this important matter.

This Association cannot yet hope to carry out large works like a Magnetic Survey from its "Grants for Research," but it should at least be in a position from these grants to help men of proved

capacity to undertake researches which involve comparatively small expenditure; or, when larger sums are involved, to give sound advice to Government on the expenditure of public money for scientific purposes.

The question of Geodetic and Topographic Survey in South Africa generally is one that I propose to deal with in greater detail in a Report to be communicated during the present meeting to Section C. It may be sufficient to state now, in a few words, the crying need for greater progress in this department.

Good maps are essential for good administration in peace as well as in war. The want of any reliable maps during the late war sufficiently proves my point in the latter respect.

In the Cape Colony and Natal the foundations have been well laid, the principal triangulation being complete. Of secondary triangulation a little beginning has been made, but only here and there is a trace to be found of sound topographic work. Thousands and thousands of pounds have been spent in surveys of a feeble, unconnected kind in the Cape Peninsula alone—far more money than enough to have mapped it thoroughly on a large scale. It is high time that the work was undertaken for the whole country, in an economical and systematic way, by a well organized department, spending at least £25,000 a year until the work is finished.

A proper Survey Department is being organized for the Transvaal and Orange River Colony, which, it is to be hoped, will shew an example to the rest of South Africa.

In Rhodesia a sound basis of geodetic triangles has been carried through a part of the country, and the British South Africa Company has provided in an enlightened spirit for the extension of the work along the 30th Meridian from the Zambesi to Lake Tanganyika, a work of great practical importance as well as of high scientific value. We welcome as a distinguished guest here to-night Dr. Rubin, who will sail from Cape Town in a few days for Chinde, as leader of the Zambesi-Tanganyika expedition. His last work was upon the measurement of an Arc of Meridian in Spitzbergen, extending to within 10 degrees of the North Pole. In North Eastern Rhodesia he will encounter a very different climate, but I am sure we all trust that he will emerge from it with no less success than that which crowned his labours in the Far North.

There are many other points on which one would wish to dwell.

For example, the successful researches of Dr. Gilchrist; he has not only made valuable contributions to marine biology, but has proved the practically inexhaustible character of our fishing grounds. This is a fact which our men of business have been too slow to recognize, but which, with reasonable enterprise in the establishment of a fleet of trawlers with cold storage, should prove not only a source of wealth but afford an abundant supply of fish at prices which would put that article of food once more within reach of the man of small means.

The results of the Geological Survey deserve special mention, as also do the entomological researches of Peringuey and Purcell, the

work of Dr. Marloth in Botany, the invaluable work of the Bacteriological Laboratory at Grahamstown, under Dr. Edington, Scully's work in ethnology and natural history, and the labours of many others besides.

But the limits of time prevent entry into so wide a field.

Let me therefore in conclusion remind you of a great historical generalization which appears to point to the fact that the time is ripe for the establishment of such an Association as this.

History teaches that all national events which call for supreme effort and self-sacrifice on part of a people and leave behind them, for a time, a legacy of untold suffering and misery, have almost invariably in the end been followed by a period of intellectual progress and development.

We here in South Africa have passed through such a crisis; pray God that it may be followed by a like result; and may this Association be one of those means which will help towards such a consummation.

Science knows no nationality, and forms a meeting-ground on which men of every race are brethren, working together for a common end—and that end is truth.

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## SECTION A.

### 2.—PRESIDENTIAL ADDRESS.

By PROFESSOR P. D. HAHN, PH.D., M.A.

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The section of our Association of which I have the honour to be President, includes, besides Chemistry, also Astronomy, Mathematics, Meteorology and Physics. Since each of those Sciences comprises so extensive a subject that man's life is too short to penetrate into all branches of any one of those Sciences, it does not require further explanation on my part why I *shall* not and cannot attempt to give a review, however brief, of the progress of those Sciences. The programme of the papers of our section refers to all those Sciences, and subjects of the different branches of all those Sciences will be discussed during the present congress. I shall, therefore, limit myself in this address to Chemistry, to the study and promotion of which I have devoted the best part of my life.

It is customary that the President of a section includes in his address a review of the progress for the last year or years of the Science which he professes. At the outset I shall give you the reasons which have induced me to deviate from this custom. The professional scientist, who carefully peruses the scientific periodicals, is regularly kept informed of this progress, and the non-professional scientist finds in the excellent reports of the meetings of the British Association, and of similar organisations in other countries, ample information on this subject, namely, the progress of research and the results of investigations in the several departments of Science. That excellent scientific publication, *Nature*, supplies its readers annually also with a *general* review of the progress of Chemistry. Here in South Africa are very few, if any, to be found, who have time, leisure, means and energy for carrying on original research, and we are therefore here greatly dependent upon the reports on the work done at the numerous seats of intense scientific activity of Europe. The professional scientist finds a *detailed* account of the progress of Chemistry in Richard Meyer's "*Jahrbücher der Chemie*," an annual publication, which I warmly recommend to my colleagues, the Professors and Teachers of Chemistry. Instead of giving on this occasion a general review of the progress of Chemistry during the last years, I intend reporting on the present state of the study of Chemistry in South Africa, and shall refer more in detail to a number of problems which fall more particularly into the sphere of work and research of those who have devoted themselves to the study of Chemistry and its application to metallurgy, agriculture and physiology. The present occasion appears to be particularly favourable for giving

such a report, because it is now the first time in the history of the intellectual development of South Africa that a scientific congress is held in obedience to the want generally felt to work with combined forces for the promotion of interest in scientific work and for the advancement of Science in South Africa. The impetus to the movement to establish the South African Association for the Advancement of Science, with its annual congress, was given by my friend, Mr. Theodore Reunert, who has also taken a most active part in the organisation of our Association. Not only the members of our Association, but all interested in the progress of South Africa, owe Mr. Reunert a debt of gratitude for his work in connection with this Association. Although mankind is not distinguished for its gratitude for favours received, I trust that the members of this Association will make an exception by always gratefully remembering Mr. Reunert as the father and founder of the South African Association for the Advancement of Science.

Let us now turn to our subject and examine the position which Chemistry holds in South Africa: its study in schools and colleges, its application to the industries, and to the development of cognate branches of science.

In order to thoroughly understand and appreciate the condition under which Chemistry is studied in South Africa we must remember that the University of the Cape of Good Hope has only been in existence for nearly 28 years, and that the syllabus of the Matriculation Examination during this time provided, and still provides, that the rising generation *may* also study a little Chemistry, if the rising generation chooses to do so, for Chemistry as well as all other branches of Science are "optional" subjects in the Matriculation Examination of our University. During all these years the University authorities must have held the opinion that the study of Science is not an integral part of the education of a young man, and during these 28 years many a young South African has become an undergraduate and subsequently a graduate in the University without even having acquired the remotest knowledge of any branch of Science.

It is hardly credible, but nevertheless it is a fact, that the University regulations allow this neglect of the study of Science in this country, of which the future depends in the first place upon the development of its natural resources, which requires above all a thorough and comprehensive knowledge of Science, which should be part and parcel of the education of every South African. For many years past we have met in almost every issue of English scientific periodicals complaints about the neglect of scientific and technical education in the schools and colleges of England as compared with those of Germany and America. It is stated that during the past century the education of the youth in England has not kept pace with the enormous and rapid development of the Sciences and their application to all branches of practical life. It has also been said that although many beautiful and stately buildings for educational purposes have been erected, the value of the scientific work done within

is in no proportion to the architectural grandeur. There are also those, and for my part I side with them, who attribute those shortcomings to the prevailing examination system which pervades all education in England, and, I regret to say, also here. I shall not follow up this subject now, for I fear my words will be like a voice in the wilderness, because this examination system is the very foundation of our University, which is merely an examining body, and it is also carefully nursed by the Education Department.

With reference to the neglect of the study of Science in our schools, I believe our Association can do much towards altering the present unsatisfactory state of affairs. It is plainly stated in our constitution that one of the objects of our Association is "to obtain a more general attention to the objects of pure and applied Science and the removal of any disadvantages of a public kind which may impede its progress." It is therefore the duty of our Association to take steps for the removal of the disadvantages under which the South African students at present prosecute their education, and to take care that the study of Science is a *sine qua non* in the curriculum of every young South African. Our Association must point out to the University Council the necessity of introducing Science into the compulsory subjects of the Matriculation Examination. In the University of London two Science subjects are compulsory in the Matriculation Examination, viz., Chemistry and Physics, but I think we should try to induce the University Council to have for the present only one Science subject amongst the compulsory subjects of the Matriculation Examination, viz., Chemistry, or Physics, or Botany. The Matriculation Examination marks in our general course of education rather the end of the school education than the beginning of academic studies. In 1901 there were 732 candidates entered for this examination, that is to say 732 young South Africans had at least for one year studied the several subjects prescribed for this examination. Of these 732 candidates, only 152, about one-fifth, presented themselves the following year at the next higher, the Intermediate Examination. What has become of the other 580 candidates who also entered in 1901 for the Matriculation Examination? They are scattered all over South Africa. Some of them having passed the Matriculation Examination have turned with most of those who failed into different walks of life. A few—very few—who failed, remained at school to try again the next year. If the regulations of the Matriculation Examination contained the condition that all candidates have to show a competent knowledge in at least one Science subject, all these young South Africans—580—would be so many seeds for spreading the interest in Science. Of course, we cannot expect those, who during their school days never came into touch with any branch of Science, to interest themselves in later years in the spread and growth and promotion of the study of Science or of scientific pursuits. What I have stated for the year 1901 repeats itself every year, only the number of candidates grows larger every year.

For these reasons I request all the members of the South African Association for the Advancement of Science to use their influence

with a view to securing to Science its proper place in the curriculum of the Matriculation Examination of the University. Considering the large number and the representative nature of the members of our Association, they have a claim to have their views on educational matters considered by the University Council. Having passed the Matriculation Examination, the young South African enters into practical life, or he takes up a profession, joining an attorney's office, studying surveying, taking up the mining course, or proceeding to a College to prepare himself for a University Degree; the larger number of the undergraduates proceed to a College. In order to get to the B.A. Examination, the student must first go through the Intermediate Examination. This examination could be passed before 1902 without the candidate taking up a Science subject, and nearly one-half of the candidates passing this Examination before 1902 did not take a Science subject. This defect has recently been remedied, inasmuch as at present a Science subject is included in the syllabus of this examination amongst the compulsory subjects, and in Chemistry the candidate has to pass even a practical examination. This is as it should be. The student who now passes the Intermediate Examination and then proceeds to the literary side will have in later years a better understanding of, and a better insight into, the great economic questions connected with the development of this country, which in the last instance are always connected with the one or the other branch of Science. The student who proceeds from the Intermediate to the Bachelor of Arts Degree in Science generally studies, besides Mathematics, also Physics or Chemistry, or both. According to my experience, the South African student possesses a considerable measure of ability for mastering the more difficult problems in the Experimental Sciences, and particularly in Chemistry. Many students have done experimental and research work in our laboratory which would be creditable to advanced and experienced students in Continental Universities.

In consequence of the inferior position allotted to Science in the education system throughout South Africa, these departments are, as a rule, inadequately equipped in Schools as well as Colleges. The teaching and study of the experimental Sciences require an equipment of apparatus and material which are soon consumed and have to be renewed from time to time. It stands to reason that in the hands of beginners apparatus suffers more than when handled by experienced men. Consequently, there is a greater expense connected with the efficient teaching of these subjects, for which provision must be made. The fact should not be lost sight of that a knowledge of the Experimental Sciences is to the young South African, when the school years have passed, of greater use than most of the other subjects contained in the school curriculum. In making provision for the requirements of education, the principal object must always be to secure efficiency, and not the desire to illustrate how cheap education can be.

Thanks to the energy of the Council of the South African College, this institution is now equipped in such a manner that effi-

cient teaching is supplied in the principal branches of Science. It is very gratifying to observe that these opportunities are made use of, as is shown by the ever-increasing number of students who take up the study of two or more Science subjects. The Chemical Laboratory, originally intended for 21 students, has become much too small, and an extension of the laboratory is now in course of construction. In other Colleges the number of students of Science subjects has also considerably increased. These institutions, following the example of the South African College, have also acquired Chemical and Physical Laboratories. Even in some schools provision has been made to do something towards teaching the rudiments of Science in Chemistry, and it is very pleasing to me that some of my former pupils are now teaching Chemistry in these schools. More could be done in this direction if the teachers of the schools could have some simplest apparatus for demonstrating a scientific fact. The principal object of the lecture experiment is to illustrate an important reaction, or chemical or physical process, which is typical for a series of similar reactions. In order to attain this object the experiment must be carefully prepared and tried beforehand, and when it comes off in the lecture it must be successful without fail, or else it deprives the student of all confidence in experimental demonstrations. To make experiments in connection with Science teaching is an art which must be taught, understood and practised; it cannot be acquired by book cramming and subsequent examination, as is unfortunately the case with most other subjects of the school curriculum.

I cannot conclude this brief sketch of the present condition of Science teaching in our Schools and Colleges without mentioning that already three South Africans who have taken the Science B.A. degree have subsequently passed successfully the Master of Arts Examination in Chemistry, and that a fair number of South African B.A. students are now prosecuting their education in different branches of Science in Universities and Technical High Schools on the Continent. They have there, on the one hand, better laboratories for study, and on the other, also, frequently an opportunity of visiting and examining large industrial establishments, in which they find the ocular demonstration of the application of scientific principles to practical purposes. To these young South Africans we must look as teachers of Science in our Schools and Colleges, and it is to be hoped that many will follow their example. Although the study of Chemistry and of the other branches of Science is still in the incipient state, there are indications which justify the hope that before long Science will have its proper place in the school curriculum, and that the experimental sciences will be taught in such a manner that they will not only prove of great practical use in after-life, but will develop the mental faculties more effectually than could be done by the prevailing system of teaching dead languages with the aid of a crib. I have already repeatedly referred to the practical use of training during vacation courses in the experimental side of the teaching of Chemistry and Physics. A teacher may be full of book-learning and at the same time unable to put up or to handle the

scientific training in after-life, and during the time I have been at the South African College I have observed many cases which support this statement. Since the opening of the Laboratory we have had always a large number of students who studied, specially, practical Chemistry with a view to using the acquired knowledge for some practical purpose or profession. Some of these specialists have become pharmaceutical chemists, others have become wine experts, others are now brewers, but the largest number of these specialists took up assaying and metallurgical work. Since 1885 more than a hundred of these specialists have studied assaying, and the majority of these have found employment, and hold good positions in connection with the mining industry throughout South Africa. During the last years the number of these specialists had to be limited, because there was no room in the Laboratory for them, all available stands being taken up by the "full course" students. As soon as the extension of the Laboratory is complete, these specialists who make the study of Chemistry a profession, will be received again. In this Laboratory, as well as in Chemical Laboratories connected with the other Colleges, the principal work of the Professor and his assistants is teaching, and it will probably remain so for some time to come, however desirable it is that original research in the various branches of Chemistry and its application to the industries should have a home in the Laboratories of the country. During the first years after the opening of this Laboratory a good deal of research work was done, more particularly in the application of Chemistry to Viticulture, Tobacco-growing, Chemistry of Fermentation, and Mineral Chemistry. But not long after the opening of the Laboratory the time of the Professor was completely absorbed by teaching, because, in addition to the teaching of Inorganic and Organic Chemistry, also Agricultural Chemistry, Chemical Technology, Metallurgy and Assaying were taken up, besides the ordinary Laboratory instruction. As these subjects are divided in Continental Colleges between three or four Professors, it is evident that one Professor cannot do full justice to all of them, and that he has no time for research work if he prepares himself conscientiously for the lectures of the several courses, and if he keeps himself abreast of the progress of his Science. It is very singular that the subject of original research is constantly mentioned in connection with the Laboratories and the Science Chairs of the Colleges, and that this question is never asked with regard to the Chairs of Classics, Literature, History, Hebrew, and Modern Languages. It is only a few months ago that objections were raised in certain quarters to the establishment of a Chair of Botany, because it was held that the time of the Professor of Botany would not be fully occupied by teaching. If it is expected of a Professor to have his time fully occupied by teaching he cannot be expected to devote a portion of his time also to the prosecution of the numerous problems in his sphere of learning which call for investigation and research. There is no person better able to point out the subjects and problems which require investigation and research in that particular branch

of Science which he professes. The farther he penetrates into this particular branch of Science the more he finds how little he knows of the subject himself, and how little is known, and how much is still awaiting investigation and research. It is therefore much to be regretted that under the present regime the Professors of the Colleges are so fully engaged in teaching that they cannot follow up original research into the many problems and subjects which present themselves, particularly in a young country like South Africa, to the student of Science, and particularly to the student of Chemistry.

May I now draw your attention to some of the problems and subjects which invite investigation and research from those students and disciples of Chemistry, who, on the one hand possesses such a thorough training in theoretical and practical Chemistry as is required for such work, and on the other hand have also time and leisure to undertake research work, which absorbs more time and closer attention than any other scientific occupation. Let us commence with *Mineral Chemistry*. There are minerals and groups of minerals here in South Africa which should be submitted to very close investigation, the results of which would be of great scientific value, inasmuch as these investigations will throw light on the mode of formation of these minerals, and will also extend our knowledge of the paragenesis of these minerals.

In Little Namaqualand there occur in connection with the copper ore deposits a large number of copper minerals which have been formed by the action of the oxygen, carbonic dioxide, and moisture of the atmosphere on the original sulphide of the ore deposit. All these minerals are basic products of oxidation of the original copper ores, and are distinguished by a definite crystallographical form, so that there can be no doubt about their individuality as mineral species. Some of those minerals are known, some not. They contain various amounts of water of crystallization and constitution. Since they have been formed under the influence of the hot and dry climate of Little Namaqualand, it would be of great interest to know whether and how far a direct influence of the climatic conditions upon the formation and constitution of these minerals could be traced.

Another interesting problem for research for the student of Mineral Chemistry is furnished at the tin ore deposits at Embabaan in Swaziland. Together with tin ore occur at this locality extraordinarily rare and most interesting minerals, such as Aischinite, Euxenite, Fergusonite, and Monazite. These minerals are not only interesting because they contain numerous rare metals, amongst them Thorium, which is now much in demand for the construction of certain incandescent lamps, but they are of special value since they contain the recently discovered noble gas Helium, which is at present mainly obtained from certain Scandinavian minerals, especially from Cleveite. Helium has been found also in certain gases issuing from mineral springs in the Pyrenees. It would be a matter of great scientific interest to ascertain whether this element is also found in the gases issuing from some of our mineral springs.

A large group of minerals, the Zeolites, hydrated Silicates, are well represented in South Africa. Of great beauty and variety are especially the Apophyllites, Natrolites and Mesotypes, Prehnites, from Kimberley, Jagersfontein, Beaufort West, and Cradock. They furnish splendid material also to the physicist, who investigates the optical properties of these minerals. They were specially valued by the famous Descloisaux, Professor of Mineralogy in Paris, who studied principally the physical properties of these Zeolites. But I know that there are found at some places, for example, near Hope-town, on the Orange River, Zeolites, that is to say, hydrated silicates of secondary formation, which are new, and not investigated yet. Beautiful specimens for the study of the paragenesis of Quartz and Prehnite are furnished by the Prehnites of Beaufort West and Cradock. These Zeolites are found and observed in the vicinity of the Dolerite, Diorite, Melaphyre dykes and intrusions which traverse the geological formation of South Africa from Simon's Town to the Zambesi. A close and detailed study and investigations of these interesting and beautiful minerals here in South Africa will not only throw much light on the formation of these minerals, but will also lead to the discovery of new, hitherto unknown, representatives of this group of minerals. The effect of the climatic conditions upon the disintegration of minerals and rocks and the secondary products formed in this disintegration is also a subject of great scientific interest. In many localities in the Karroo are found pebbles of ferruginous clay, which are surrounded by a coating of Magnetic Oxide of Iron, which is undoubtedly formed under the influence of the hot and dry state of the air of the Karroo during a considerable part of the year. Another problem which calls for investigation are the products of the disintegration of Doleritic and Basaltic rocks. At some localities, for example, near Colesberg, the Dolerite hills are white, as if they had been whitewashed from the Carbonate of Lime formed in the decomposition of the rock; at other localities the same rock has put on a protecting coat of Oxide of Iron, and at others it crumbles to a sandy powder, yielding a dark red-brown soil. Also the oil shales between Kimberley and Boshof are not investigated yet as to their nature and commercial value. Equally interesting for scientific investigations are the Quartz crystals found near Carnarvon, containing cavities partly filled with oil—rock oil; also the rock in which these crystals occur contains rock oil. Now there is a great difference between Hydrocarbons making up the American rock oil and those of the oil from Baku on the Caspian. It would be of great scientific interest to know what the composition and constitution of the oil is which has been found at certain localities here in South Africa.

There is one more subject I should like to draw your attention to, although many others could be mentioned. In some of the caves on the coast near Saldanha Bay is found a peculiar deposit of Phosphate of Lime, closely resembling the Phosphorites of Spain and the hard Sambrero guano. This is evidently formed of the guano of seabirds. It is quite a unique formation, a fossilized guano.

A somewhat analogous formation is observed in the numerous caves found on that grand block of mountains between Worcester and the Bokkeveld. In nearly all these caves occurs Bat guano, and below the guano on the bed rock is generally found a stratum of white crystalline saline matter, composed of two or three compounds, which can be separated by fractional solution and crystallization. They are Phosphates of Ammonia and Potash. Now, these phosphatic deposits of the caves throughout South Africa also call for investigation are the products of the disintegration of Doleritic and under the heading of Mineral Chemistry.

Closely connected with the analyses of minerals are those investigations which are directed to the composition of soils, and which are undertaken more with a view to a practical object. We cannot withhold our recognition from the work which has been undertaken and carried on in the Agricultural Department in connection with the investigation of soils of the Colony. They were first undertaken on the coast and grain districts of the Colony; that is, to say, of those districts in which the soil consists of the products of the disintegration of metamorphous slates, sandstones, and intrusive granite, Malmesbury, Paarl, Stellenbosch, Cape, and Caledon. The results of these investigations are, so far as they have gone, of eminent importance for the various branches of agriculture, and these results should now be turned to use. The mere analyses of the soils are of little immediate use. The value of these analyses depends upon their correct interpretation and upon their application to practice. The numerous results of these investigations most definitely prove that all the primary soils formed of the previously mentioned rocks, viz., metamorphous slate, sandstone, and granite are poor in all the essential constituents of plant food, more particularly in lime. The amount of Phosphoric Oxide is very low; only Potash occurs in such quantity that crops requiring Potash may be cultivated with advantage, such as the vine, grain, and potatoes. The leguminous plants, clover and lucerne, and also tobacco, do not find in this soil sufficient plant food, especially lime, for a healthy and luxuriant growth. We know that lime is an indispensable constituent of plant food, that it is specially accumulated in old leaves, in bark, in wood, whilst potatoes, carrots, and also grain, and those young parts of plants in which the vital functions are most active, buds, young shoots, and young leaves do not contain or require a larger supply of lime. Whilst wheat (grain) takes of one hectare 1.04 kilograms of lime, and potatoes (tubers) 4.19 kilograms of lime, the same area loses through cultivation of clover 111.8 kilograms, and through tobacco 153.7 kilograms (Ehermeyer, *Chemie der Pflanzen*). These latter were already called by Liebig lime plants. This great scientist also recognized the fact that the specific physiological functions of one mineral constituent in this system of plants could not be performed by another, and that these lime-requiring crops do not thrive on soil poor in lime. Of still greater importance are these investigations into the soils of the Western Province for Forestry and Arboriculture. All kinds of trees grown in the forests

of Europe are distinguished by containing a very large amount of lime, but a comparatively small amount of potash and phosphoric oxide. In one of the principal works which deal with the subject "The Chemistry of the Forests," the following statement is prominently put forward: "It is of the utmost importance for a rational system of forestry to remember that all kinds of trees require a very large amount of lime as compared with the agricultural crops. A large production of wood can only be expected where the soil supplies besides the other mineral constituents, also the large demand of trees for lime." I will only quote here from the same work, that the beech tree takes of one hectare annually 96.34 Kg. of lime, and the fir tree, which is extremely modest in all its requirements, as much as 28.61 Kg. These quantities considerably exceed the amount of lime which is taken by the cultivation of wheat or potatoes from the same area. What is known about the requirements of the trees recommended here in South Africa for afforestation? Have any investigations already been made in this direction? Have these important results obtained by the investigations into the composition of soils been turned to use by the Forest Department or in fruit-growing? There have been very singular failures recorded in fruit-growing in the Western Province, where the primary soils are very poor in lime. It must be remembered that the apple and pear tree require more lime than other fruit trees, and these again more than the forest trees. Has any attention been paid to these vital questions by the Forest Department or by Fruit-growers' Associations? I am afraid it is not fair to ask such questions at a time when Forestry and Arboriculture have been in existence in South Africa for only a few years. The afforestation of South Africa, wherever it can be carried out, is of such eminent economic importance that our Association should take up a definite attitude with regard to this matter. The South African Association for the Advancement of Science should appeal to all the Governments of the South African States to combine in order to establish one common Forest Academy for South Africa. Such institutions exist in some of the Continental States, and there should be no difficulty in establishing one for South Africa. In this institution the young forester should be practically and scientifically trained for his profession with due regard to South African soil, climate, and forests. In this institution everybody should be able to obtain information and advice on tree-planting and fruit-growing. In such an institution those scientific investigations of soils, requirements of trees, and other matters should be carried out on which a rational system of forestry and arboriculture can only be based, and the nurseries, plantations, and forests connected with such an institution would soon yield sufficient value to make it self-supporting.

I now appeal to all the members of the South African Association for the Advancement of Science to give support to the movement to induce the several Governments of South Africa to establish one common Forestry Academy for the United States of South Africa.

I cannot leave this subject without once more drawing your attention to the use and application of scientific investigations to practical purposes. I have already mentioned that forest trees take off a given area more lime than potatoes. Since the time of Liebig it has been known that of all our fruit trees the apple tree requires the largest amount of lime, and thrives best on calcareous soil. Who is not reminded of this fact when he sees the poor apple trees full of insects and fungi, grown on the soils poor in lime, and compares these with the healthy, large, well-developed apple trees grown in Worcester, Robertson, Montagu, and Ladysmith, where the soils of the orchards contain a fair amount of lime.

It is regrettable that there is also in arboriculture such an utter disregard of scientific principles. "Everything has to be practical; everything has to be based on practice." A continuous repetition of this routine is merely an excuse for the ignorance of scientific principles. But I think it is the most "impractical" procedure to disregard certain facts which are results of scientific investigations. To follow practice alone is as unreasonable as to work on theory only. No branch of human occupation has for its progress been more dependent upon a combination of theory and practice than agriculture in the widest sense of the word, including also fruit-culture, arboriculture and viticulture. The high development which the several branches of agriculture and agricultural industries have attained in Europe and America is in the first place due to a proper and systematic application of the results of scientific, more particularly chemical, investigation and research. This is the only road which leads to progress and success, and we in South Africa have to follow in order to emerge out of the present unsatisfactory amateur stage, and to become true and real progressives.

A most important branch of Agriculture in the Cape Colony is Viticulture. The work of the wine-farmer is partly of a purely agricultural nature, namely, the work in the vineyard, and partly of an industrial or technical nature, namely, the making of the wine and the distilling of brandy. It is well known that the Colonial wine-farmers take a keen interest in the work in the vineyard, and have shown in this part of their work an unusual aptitude, which manifested itself during the last ten years in the reconstruction of the vineyards destroyed by *Phylloxera*, by planting grafted American stocks. I have seen reconstructed vineyards in some parts of the Colony which could not be surpassed in any wine-producing country in the world. The cellar-work throughout the wine districts is, however, not in a satisfactory state. In explanation of this it has been said that it is only natural that a man who is accustomed to open air work does not feel inclined to do work in close, confined cellars, and that for this reason the cellar-work is not attended to as it should be. I am not satisfied with this explanation at all. Wine-making is by no means a simple operation, which may be done in a haphazard way. In order to produce a sound wine, which need not be Pasteurized, or fortified, or doctored in some way, it is indispensable to pay close attention to the principles of Chemistry. Every wine-

farmer should possess an accurate knowledge of the principles and conditions of alcoholic fermentation and of the acetic acid fermentation, to follow the one and to avoid the other. I know, however, from experience, that there are very few wine farmers who possess some knowledge of the rudiments of the Chemistry of Fermentation and are able to apply its principles to practice. What is the use of spending labour, energy and treasure on growing and producing those splendid grapes for which the Cape is famous if at the same time care be not taken to produce at least a sound wine? The attempts hitherto made with a view to spreading amongst the wine-farmers a better understanding of the principles of fermentation and of wine-making have for some reason or other not been altogether a success, and much remains to be done in the future in this direction.

Closely connected with wine-making is the distillation of brandy, also a branch of Chemical Technology. It is astonishing how large the losses are which the brandy-producers annually suffer from want of knowledge of the very rudiments of the principles of the Chemistry of Fermentation. In some of the wine districts nearly all the wine is used for making brandy, and since on most of these farms fustage is insufficient, distilling and pressing is going on at the same time, and the young wine, containing still 6 per cent. to 10 per cent. of sugar, is distilled, and the yet unfermented sugar is thrown away and lost. About 22 years ago I tried to ascertain, at least approximately, the amount of loss which the brandy industry suffered annually through this procedure. Assuming that the average of sugar in the juice was 20 per cent., I found that the loss of brandy amounted to at least 33 per cent. of what was produced, because all the young wines submitted to distillation contained still over 5 per cent. of sugar, one-third of the amount which had undergone fermentation.

I have treated this subject a little more fully to give an example which illustrates how the want of knowledge and the neglect of scientific principles directly affect the revenue of the people. I could give several other examples of the same type, but this may suffice.

We can hardly speak in South Africa at present of the application of Chemistry to technical and industrial purposes on a large scale, if we exclude the two large Dynamite Factories near Somerset West and Johannesburg, which have been called into existence through the development of the mining industry, and which are to serve the further development of this industry. The several small attempts which have been made in connection with the production of cement, of glass, of pottery, and of sulphuric acid have not been successful. Some of these industries soon disappeared again, and the others have not prospered as they should.

It is worth while to approach the question whether the conditions for the development of extensive chemical industries exist in South Africa or not. These conditions are of a social and of a material nature. We shall only review the latter, because they are more permanent than the ever-changing and fluctuating social conditions. The principal of the material conditions for the development of chemical industries is an ample supply of sources of energy. The

first question is, therefore, are there sources of energy in South Africa available for developing and for maintaining chemical industries? If we divide South Africa by the meridian of De Aar into two parts, we find, by comparing those two parts, in the Eastern part rich diamond mines, gold mines, and ore deposits of nearly all metals of technical importance—Silver, Copper, Zinc, Tin, Lead and Iron. This part of South Africa is at the same time also distinguished by possessing large coal deposits at Indwe, Cyphergat and Molteno in the Colony, in the Transkei, in Natal, at Vereeniging in the Orange River Colony, at Brakpan, Middelburg and Wakkerstroom in the Transvaal, at Wankie and on the banks of the Zambesi in Rhodesia. At present, coal is still the prime motor power in chemical as in other industries. For example, it would be impossible to extract the gold at the Rand with a profit if, instead of using the cheap coal of Brakpan, near Johannesburg, the mining industry had to buy coal at the rate which now rules in Cape Town. In addition to the coal, we have in the Eastern part of South Africa a large supply of water-power, which can be transferred into mechanical and electrical energy. An approximate estimate of this water-power in the Transkei and Natal gave the result that the available water-power in the Transkei and Natal is equal to that of Germany and Switzerland combined. Whilst in Germany and Switzerland the employment of this water-power has given a powerful impetus to the further development of chemical industries, nothing whatever has been done as yet in South Africa as to the utilization of these sources of energy. At present enormous masses of water still run from the Drakens Bergen in numerous rivers, cataracts and waterfalls to the Indian Ocean, as it has been in the past, without yielding a unit of energy towards the industrial development of South Africa.

The Eastern part of South Africa has been well provided by nature, possessing, besides rich ore deposits, fertile soil and favourable climate, also the two principal factors required for the development and maintenance of chemical industries, coal and water-power, transferable into mechanical and electrical energy. There is no doubt that these favourable conditions will before long be turned to use for chemical industries, as one of them, the coal, is already employed for the mining industry.

And what do we find in that part of South Africa to the west of the meridian of De Aar? At present there has been found nothing besides the Copper Ore in Little Namaqualand and the little Gold in the Knysna which justifies the hope of having also in this part of South Africa flourishing mining industries. In the Western part of South Africa no indication of coal has been as yet discovered, and the water-power transferable into energy is very poor. Here and there, for example at Jonkershoek, in Mitchell's Pass, in Southey's Pass and in the Knysna, are a few localities where water-power can be transferred into mechanical energy, but in most of these cases only during a portion of the year. A successful development of coal-consuming industries, or rather energy-consuming industries, is, in the Western Province, out of the question.

These considerations lead us to the conclusion that the chemical industries have a great future in the Eastern part of South Africa but not in the West, because in the East we have an abundance of all those material considerations upon which the development and growth of all technical industries, and principally chemical industries, depend, whilst the West will also remain in future more or less what it is now, a thinly-populated country, with a little agriculture and viticulture in some favourably-situated localities of the coast districts, and sheep and cattle-farming in the Karroo districts.

But let us return from this contemplation of future prospects to the present time. One branch of Metallurgy, which is simply another name for Chemical Technology of Metals, has, in connection with the gold industry, been considerably advanced through the work and research of able and competent scientific workers. I refer to the development of the Cyanide Process, without which the Rand gold industry could not exist. I shall not enter into a discussion of this process, since we are going to have a paper on this subject by Mr. W. A. Caldecott, which I have no doubt will be highly valued by all who take an interest in the gold industry.

It must be remembered that the study of the Metallurgy of Gold, as well as of every other metal, is based upon an accurate and extensive knowledge of Chemistry, and that in the school curriculum of the young metallurgist ample provision must be made for the training in theoretical and practical Chemistry. A mere superficial knowledge often proves in this subject disastrous, and teachers and students alike of Metallurgy must pay special attention to accuracy and exactitude of observation, because slightly altered conditions and circumstances are frequently accompanied in metallurgical operations by the gravest consequences.

Finally, I mention a few points in connection with the Chemistry of Plants and Vegetable Physiology, which particularly deserve the attention of those who intend taking up original research in this direction. Here in South Africa we have a flora as rich and varied as is found nowhere else in the world. The work of botanists has been chiefly confined to systematic botany, and very little—almost nothing—has been done in the chemical investigation of plants and plant-products. The alkaloids, glycosides, resins, oils, and aromatic compounds which exist in many South African plants still await discovery, scientific investigation and practical application. These investigations are, however, by no means so simple; they require, in the first place, a thorough training in Chemistry, particularly in Organic Chemistry, then an equally thorough training in the analysis of organic compounds and an extensive knowledge of the various methods in use for the extraction of the active principles of plants, in short, the research chemist has to pass through a lengthy and difficult preliminary training before he is competent to produce, in this branch, work of scientific value. Notwithstanding this, I should recommend this field of research particularly to South African students, because they find here better and more plentiful material for their investigations than in Europe. If it be true also for South Africa that it is

the unexpected which happens, that, for example, a millionaire were to give a portion of his treasure to research work, a considerable part of this should be devoted to lift the veil which still wraps in darkness this field of research. I expect from the investigations in this field results which will be as interesting as they will be important.

Vegetable Physiology also presents in South Africa many interesting problems to the student of Chemistry, of which I may be permitted briefly to mention a few.

It is known that the composition of the mineral constituents of the leaves of plants vary considerably during the annual period of vegetation, although the different plants and trees exhibit a certain predilection for the one or the other of these mineral constituents. Whilst most of the forest trees of Europe contain in the leaves in spring principally Potash and Phosphoric Oxide, these constituents disappear almost completely in autumn, and the ashes of leaves consist then almost entirely of Silica and Carbonate of Lime. From a scientific point of view, it is of interest to know how these changes proceed under the climatic conditions of the Cape. One investigation of leaves or other parts of plants during the annual period of vegetation is not sufficient, and of little value. To obtain a clear insight into the circulation of the mineral constituents within the plant, and into the requirements of plants, it is indispensable to have a series of investigations, methodically planned and systematically carried out, which should in the first place be directed to the crops we cultivate, to the fruit trees, and to the forest trees. These investigations require much time and perseverance, and should be carried out in the laboratories of agricultural stations or of a forest academy.

Another problem of scientific interest and economic importance presents itself in the comparative nourishing value of the crops we grow. This depends upon the quantity of carbo-hydrates and albuminous compounds contained in these crops. It is known that the production of the albuminous compounds in sunny climates is much larger than in cold climates, with an ever-cloudy sky. It is a matter of importance to investigate this subject in connection with the leguminous plants, such as peas, beans, lucerne and clover. This question is also of importance for the cultivation of cereals, more particularly of barley used for brewing beer. There is no doubt that the barley grown in South Africa possesses a higher nourishing value than the English barley, because it contains a larger proportion of gluten, that is, albuminous substance, than the English barley. But this is the very reason why the Cape barley is less suitable for brewing beer than the English barley, because the presence of too much albuminous matter in the beer is not desirable for brewing. Similar observations have been made in grapes grown on the hillside or on vlei-soil and in vineyards which are occasionally irrigated. The grapes grown on a hillside contain less albuminous matter, they yield a better quality of wine, and the making and maturing of this wine presents no difficulty, whereas the grapes grown on vlei-ground or irrigated vineyards, contain more albuminous substance, and the making and maturing does not proceed so smoothly,

These and other similar subjects are of great importance for Agriculture and Viticulture, and can only be solved by the application of Chemistry to these branches of Agriculture. Similar questions present themselves in connection with the cultivation and preparation of tobacco, with the growth of sugar beetroot and other branches of agriculture. It would take too long to discuss on this occasion all the others.

In conclusion, I take leave to point out once more that the object of the South African Association for the Advancement of Science is to promote the study of Science and its application to practice. I have, therefore, appealed to all the members of our Association to use all their influence to induce the University Council to introduce one Science subject into the list of compulsory subjects at the Matriculation Examination. I have no doubt that the University Council will meet, as far as this can be done, the request of our Association. I also believe that our Association possesses sufficient influence to induce the Governments of the several States of South Africa to combine with a view to the establishment of one common Forest Academy for South Africa. In each of the States of South Africa there should be established Agricultural Experimental Stations, supplying a home for scientific research bearing on agriculture in all its branches. These institutions will assist South African Agriculture, Viticulture and Arboriculture in emerging out of the present unsatisfactory condition of tentative dilettantism. Money is being spent to build Museums and to pay officers of the Museums, and much money has also been spent for Art Schools and for maintaining the same, and ample grants are now coming forward for the Agricultural School since it came under the present *régime*. This is as it should be. Why should we hesitate any longer to establish these institutions—Forest Academy and Agricultural Stations—and to engage the best men for working these institutions, which are of such eminent economic importance for the development of the agricultural resources of South Africa on a sound basis, a basis consisting of a combination of theory and practice? There are many other subjects bearing on the promotion of the interest in Science and its application to practice. We must not undertake too much at once. Our Association will have achieved much if we succeed in securing the co-operation of the University and of the Governments of the States of South Africa for carrying into effect the proposals which I have more fully referred to in this address.

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### 3.—ON FERMENTS CAUSING "CASSE" IN WINES.

By RAYMOND DUBOIS, Diplômé E.A.M., B.Sc., F.C.S., F.S.C.I.  
(Victoria), Government Viticultural Expert.

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#### INTRODUCTION.

Since the grafting of our wine varieties on American *Phylloxera*-resistant stocks, wines seem often to suffer from a disease which presents the following characteristics.

Wines which are bright in colour and seem perfectly sound suddenly modify their colour when exposed to the air. They become brown and turbid, their cloudy appearance rendering them unfit for sale.

If the wine is contained in a glass jar, where it can be observed, it will be noticed that the discolouration starts from the surface exposed to the air in the form of a thin veil of colouring matter and little by little sinks in the liquid forming a brown-black precipitate, which adheres to the sides of the jar. In a few days the wine completely loses its original colour, assuming a very characteristic straw colour.

Racking or decanting seems to increase the decomposition instead of checking it, as is the case with other wine diseases. This disease, known among French wine-makers under the name of "casse"—Break—on account of the sudden break in the colour, may be frequently noticed in both red and white wines made from over-ripe grapes. So common has it become that it has been the subject of numerous studies by several distinguished oenochemists, as may be seen from the appended bibliography.

Most of the authors who studied this disease found in the affected wines blackish matter, partly in solution, which, according to them, would be the cause of the alteration in the colour. They attribute to this matter, acting as an oxydase, the property of fixing the oxygen on the various constituents of the wine, of oxydising it, if we may use such an expression, this oxydisation causing the break in the colour.

The present studies were undertaken with the object of ascertaining how the *black matter* was formed in the wine, its composition and mode of action, and the way of checking its formation.

Five litres of affected wine were concentrated by evaporation at 60° C. The residuum treated with water and brought to boiling point was left to cool down. During the process of cooling down an abundant cloud of blackish matter precipitated at the bottom of the vessel. It was found to be composed mainly of albuminoid and pectic matters. This precipitate placed on a filter was washed

several times with distilled water and mixtures of alcohol and ether to remove mineral and organic salts.

Microscopic examination of the residuum did not reveal any micro-organisms other than those usually found in wine lees.

Mixed with sound wines it decomposed in the course of three or four days, and the wines showed all the characteristics of wines affected by "cashe."

This experiment was repeated with different types of wines, and it was noticed that the phenomenon did not take place with the same intensity with all wines. Some could be brought back to their normal state by fining; others could not. The former, when mixed again with black precipitate, would resume the characteristics of broken wine.

#### APPARATUS USED.

Several glass flasks of special shape (A, a) Fig. 1. The lower extremity tapering to a capillary point hermetically sealed by fusion, the upper part provided with a neck and bulb, which may be closed with a plug of sterilized cotton wool (D).

The apparatus G, shown in Fig. 1, is composed of two similar parts E and F. Each part is composed of a porcelain filter fitted in a brass ring (B, b) provided exteriorly with a thread, on to which is screwed a second ring (H, h) carrying a tin vessel provided at the bottom with a tube (O, o) and tap (P, p). A cap (K, k) surmounted by a tube (L, l) carrying a bulb (N, n) and funnel (M, m) is screwed over the tin vessel.

Tube O is fixed by an india-rubber coupling to a special wide-graduated tube (S). Tube O is fixed in the same manner to a bottle (T) provided with three necks, the centre neck having a capillary constriction at (V). Tube (S) and bottle (T) are each provided with a horizontal tube narrowed at (e), and stopped with two plugs of cotton wool. A fine tube (X) joins the bottom of tube (S) to the top of the bottle (T). Bottle (T) bears a mark, indicating 1000 c.c.

#### EXPERIMENT.

150 grammes of affected wine (in which the proportion of black matter has been previously measured) are placed in flask (A) previously sterilized at 150°C. The neck is plugged with sterilized of — 15°C. for 24 hours.

One litre of sound wine is placed in flask (a), plugged and sterilized in the same manner.

The whole apparatus G is also sterilized by keeping it at a temperature of 120°C. for several hours.

The required quantity of broken wine is introduced into tube (S) in the following manner. The capillary extremity of flask (A) is passed slowly through the cotton wool of funnel (M), and flamed at the same time with a Bunsen burner until it reaches tap (R), which is left open. The cotton wool in funnel (M) soon ignites, and is replaced by new cotton wool to keep the flask in position.

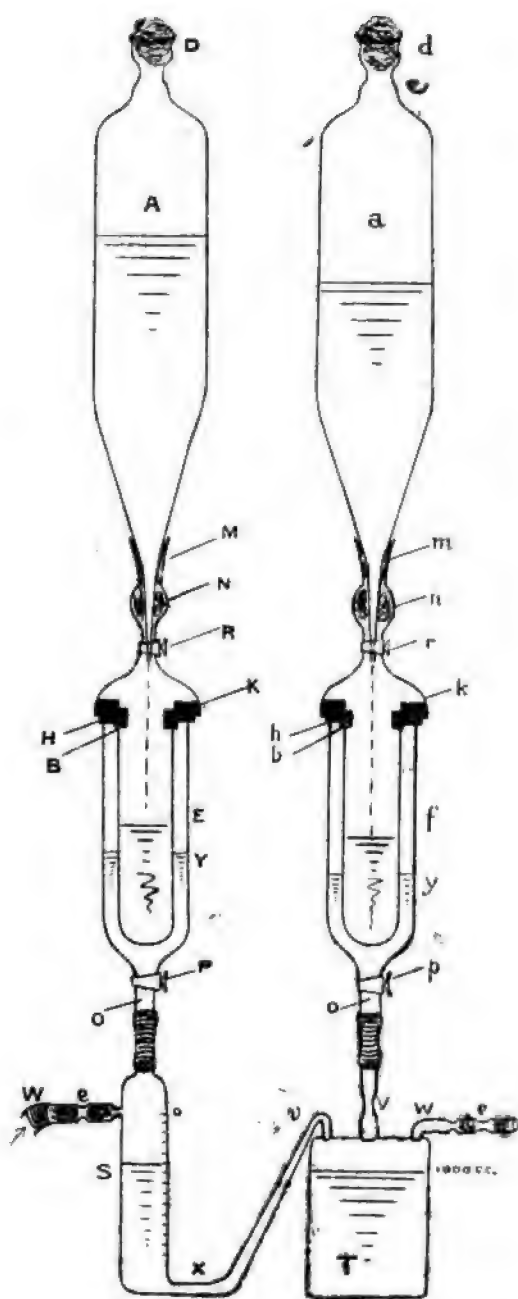


Fig. 1.

Flask (a) containing the sound wine is passed in the same way through funnel (M).

By slightly turning taps (R, r) the capillary tips are broken off, and the liquids fall into the porcelain filters, and through them in vessels (Y, y).

After a few moments, tap (P) is open, and the liquid adjusted to the zero of the graduation on tube (S).

The required quantity of this liquid is then introduced into bottle (T) by blowing carefully through tube (W) and watching the graduation.

Tap (p) of the second part of the apparatus is then open, and bottle (T) filled with sound sterilized wine up to the mark (1 litre). The bottle is then separated from the apparatus by fusing the constrictions (V, v) with the blow-pipe. The bottle is left in that state for a few days.

### RESULTS.

From repeated experiments with this apparatus the following conclusions were arrived at:—

1. All sterilized wines mixed with sterilized broken wine break after a few days.
2. For a same wine, breakage is proportionate to the quantity of broken wine mixed with it up to a certain limit.
3. For a same quantity of broken wine introduced into a given quantity of sound wine breakage is in inverse proportion to the intensity of the colour.

It is evident that if the black matter is the result of a chemical reaction between certain components of the wine, by mixing broken wine with sound wine, we introduce into the sound wine, elements capable of increasing the proportion of black matter. After four or five days, when the mixture had acquired all the characteristics of broken wine, the quantity of black matter in bottle (T) was measured and found in every case to be equal to that introduced with the broken wine. Hence we conclude:—

1. The black matter is not the result of a chemical reaction.
2. The break is due to this black matter.
3. The black matter is not formed at the expense of the colouring matter, but acts on it.

### HOW DOES THE BLACK MATTER ACT ON THE COLOURING MATTER?

Wine contains three kinds of colouring matter.

1. Red matter known under the name of Rhodoganeine.
2. Blue matter known under the name of Cyanoganeine.
3. Yellow matter known under the name of Pheoganeine.

It is the blending of these three matters in various proportions which gives the wine its "robe."

Rhodoganeine and Cyanoganeine have often been confused under the name of Cœnocyanine. According to Bouffard this matter has the property of turning red under the influence of acids, and blue under the influence of alkalis. This would seem erroneous in view of the fact that Jacquez wine, known for its blue colouration, often contains a greater proportion of acids than red wines.

Pheoganeine is generally admitted by oenochemists—Bouffard, Roos, Martieu, etc. It is due to the absence of the two other colouring matters that very old wines owe their yellow straw colour.

With the object of studying these three colouring matters, the three following wines were selected:—

1. Tinturier wine (Pontac)—Rhodoganeine predominating.
2. Jacquez wine—Cyanoganeine predominating.
3. And very old wine—Pheoganeine predominating.

These wines were treated with tribasic acetate of lead. The precipitate placed on a filter was washed several times with distilled water, until the filtrate ceased giving a precipitate with ammonia. The precipitate was then heated with sulphuretted hydrogen, and again filtered. In the filtrate we had the colouring matter mixed with  $H_2S$ , which was liberated by reduction on a water bath at about  $40^{\circ}C$ .

The following are the reactions of acid, alkali, and oxygen on the three solutions:—

Acid (weak sol.) intensifies the colour of Rhodoganeine, turns Cyanoganeine red, without action on Pheoganeine.

Alkali (weak sol.) turns Rhodoganeine blue, without action on Cyanoganeine and Pheoganeine.

Oxygen turns Cyanoganeine yellow, Rhodoganeine slightly yellow, without action on Pheoganeine.

These may be condensed in the following table:—

COLOR.	ACIDS.	ALKALIS.	OXYGEN.
Rhodoganeine	Intensifies Colour	Turns Blue	Turns Yellow
Cyanoganeine	Turns Red	Without Action	" slight Yellow
Pheoganeine	Without Action	Without Action	Without Action

Pheoganeine is therefore the most stable. Concentrated acids and alkalis are without any action on it, while they turn the two other colours brown, and decompose them. The "mutage" (discolouring) of wines is based on this property.

If 20c.c. of red wine are treated by 10c.c. of pure  $SO_2 H_4$  the reaction is very marked. The solution diluted with water and filtered will contain Pheoganeine in solution.

This solution saturated with Carbonate of Baryte, filtered and concentrated in a vacuum, will give a pure solution of Pheoganeine.

Yellow wines, such as those used in the manufacture of Vermouths, are unaffected by precipitating reagents, for they only

contain Pheoganeine, the two other colouring matters being decomposed by a slow reaction.

Some old yellow wines contain a small quantity of Rhodoganeine. If acid is added—if they are mixed with soda water, for instance—the colour of Rhodoganeine is intensified, and becomes apparent. If the acid is saturated by an alkali, the wine resumes its former colour.

If we consider that “casse” does not modify the percentage of acidity (Lagatu) and if we admit that it is caused by the black matter, we must conclude that the black matter is without action on the Pheoganeine, but acts on the two other colouring matters.

### HOW IS THE BLACK MATTER FORMED?

From the above experiments we may consider two kinds of “casse.”

1. “Casse” produced in wines spontaneously, the cause being unknown. We shall call it *natural*.

2. “Casse” produced by mixing broken sterilized wine in sound sterilized wine. We shall call it *experimental*.

Numerous analyses of wines easily broken show that they are all deficient in tannin and rich in albumenoids. Both these results are explained one by the other, tannin having the property of precipitating albumen. “Casse” would, therefore, appear to be due to an excess of albumenoid matters in the wine, in the first instance. This view seems confirmed by the fact that as “casse” increases the proportion of black matter increases, while the quantity of albumen diminishes.

We must conclude that the *black matter is formed at the expense of the albumen*.

We saw how the black matter was measured. The decrease of albumen was ascertained in the following way:—

Five litres of affected wine are evaporated in a vacuum. The residuum dissolved in pure hydrochloric acid. The solution reduced to 1 litre by evaporation, 10 grammes are saturated with oxide of silver, filtered and tested with Millon's reagent. The intensity of the colour allows an approximate estimation of the proportion of albumen.

We tried to produce natural break in a wine artificially albuminated. Introducing albumen in the wine was found useless, as it simply acted as a fining. We required the albumen in solution. This was obtained by adding to a must rich in glucose an albumen solution before fermentation. The resulting wine was rich in albumenoid matters, and broke very easily. When broken wine was added to it, it showed, after a few days, the phenomena of “casse” in an exaggerated form, with decrease of albumen and formation of black matter in greater quantity than that introduced with the affected wine.

After our first experiment we concluded that the discolouration was not attributable to a chemical action alone. To further ascertain whether this was the correct view, we repeated our first experi-

ment by replacing the sound wine by albuminated wine. After a few days the quantity of black matter in bottle (T) was measured, with the result that it was found to be equal to that introduced with the sterilized broken wine. We concluded that "casse" was caused by a ferment, which, acting on the albumen, produced a black matter decomposing rhodoganeine and cyanoganeine and turning them brown.

#### FERMENT OF "CASSE."

The next series of experiments was undertaken with the object of discovering that ferment. A solution of sterilized pure albumen was inoculated with broken wine kept for 24 hours at  $-15^{\circ}\text{C}$ . The sterilized solution of albumen in flask (A) was filtered through (F) in bottle (T) and the constriction sealed with the blow-pipe (Fig. 2).

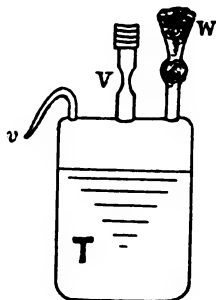


Fig. 2.

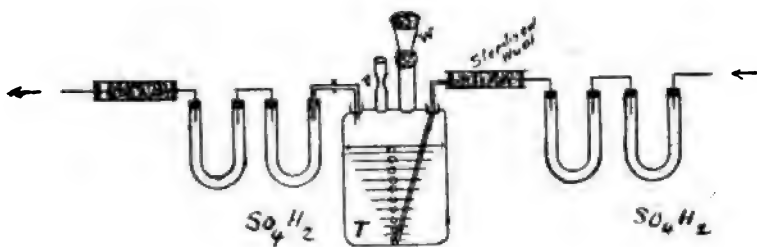


Fig. 3

The solution was then inoculated with a capillary tube through neck (W). In every case putrid fermentation took place, the bacteria of butyric fermentation being able to resist a temperature of  $-15^{\circ}\text{C}$ .

A device had to be found to prevent the butyric bacteria from developing. Apparatus (Fig. 3) was used, based on the facts that

butyric bacteria are anaerobic, while the "casé" bacterium is aerobic (air being a necessary condition of the phenomenon of "casé").

A pure solution of sterilized albumen is introduced in bottle (T), as explained above, and constitution V is sealed. After inoculation, a current of sterilized air is constantly passed through the liquid.

After a few days the solution becomes turbid, and a black precipitate, similar in appearance to that formed in broken wine, settles at the bottom of the bottle. This deposit examined under a magnification of 1000 to 2000 diam. showed very long slender filaments, transparent, fringed, and free from inclusions of colouring matter, mixed with a few leucidal, saccharin, and specks of organic dirt.

These filaments, which do not seem to have been observed up to the present, would belong to the leptothrix group. They may be considered as the first cause of the disease.

We may now condense the whole phenomenon in the following:—

A bacterium (leptothrix) developing in wines rich in albumen acts on that albumen by fixing ox. and water, and produces a diastase which has the property of turning rhodoganeine and cyanoganeine brown.

#### MEANS OF CHECKING THE DISEASE.

Since this bacterium only develops in wines rich in albumenoid matters, one of the remedies consists in adding tartaric acid to the wine directly after fermentation. But by far the most effective means of checking "casé" is Pasteurization by heat, which has given such reliable results with other wine diseases.

With the object of ascertaining the effect of temperature on this ferment, series of small sterilized test tubes were filled with recently-broken wine, plugged with sterilized cotton wool, and placed in a water bath, the temperature of which was kept constant. Each series of six tubes was sterilized at a different temperature, the temperatures being 60°, 65°, 70°, 75° and 80°C., each tube in each series being left in the water bath for varying lengths of time, i.e.,  $\frac{1}{4}$  min.,  $\frac{1}{2}$  min.,  $\frac{3}{4}$  min., 1 min., 2 min., and 3 min.

The following table gives the results of this experiment:—

TIME OF IMMERSION		TEMPERATURES.				
		60	65	70	75	80
$\frac{1}{4}$ minute	...	1st day	1st day	3rd day	3rd day	nil
$\frac{1}{2}$ "	...	1st "	2nd "	3rd "	nil	nil
$\frac{3}{4}$ "	...	1st "	2nd "	4th "	nil	nil
1 "	...	1st "	1st "	3rd "	nil	nil
2 "	...	1st "	5th "	nil	nil	nil
3 "	...	1st "	nil	nil	nil	nil

The above figures show the number of days which elapsed before the wine, which had started to settle before sterilization, showed any signs of recurring "cassee." In the cases where "1st day" appears, it means that heating had no appreciable effect. In cases where the word "nil" appears, it indicates that after one month the wine had not shown any new sign of "cassee," and in some cases had become bright, leaving at the bottom of the test-tube a brown deposit.

It results from the above that a temperature of  $75^{\circ}\text{C}.$  acting for at least  $\frac{1}{2}$ -minute, is required to kill the ferment and its diastase. In practice, this temperature should prove sufficient, as in most modern wine Pasteurizers the wine remains in contact with the warm water for at least two minutes.

Before ending this paper, we must draw attention to the fact that this temperature of  $75^{\circ}\text{C}.$  is much higher than that required to kill micoderma vini, micoderma aceti, tourne or amertume ferments. According to Gayon's experiments, these diseases may be effectually checked by allowing the wine to remain for 2 min. at a temperature of  $60^{\circ}\text{C}.$

This means that greater care must be observed in excluding air during the process of heating and cooling, or the wine would acquire a cooked taste.

It would be interesting to ascertain whether the duration of effectual heating is function of the alcoholic strength and acid percentage of the wine.

The wine experimented upon contained 10.6% of alcohol by volume and 5.1 grammes total acidity.

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#### 4—METEOROLOGY IN SOUTH AFRICA—A RETROSPECT AND PROSPECT.

By CHARLES M. STEWART, B.Sc.

As this is the first meeting of our Association, which has for its main object the encouragement and development of all branches of scientific inquiry in South Africa, it seems not only suitable but absolutely essential for us to be placed in possession of a plain statement of the facilities given for the study of each particular branch of Science, as well as of the amount of work actually carried out, so that we may be in a position to see clearly its strong, and more especially its weak points, and consequently be able to indicate along what lines development ought to proceed.

It is, accordingly, with this object that I venture to lay before you the following remarks on the rise and progress of Meteorology in South Africa.

##### HISTORICAL SKETCH.

Although occasional notes on the state of the weather prevailing at Table Bay appear in the Journals of the early Dutch Governors of the Cape, the first regularly-kept record of meteorological phenomena seems to have been that of the Abbé de la Caille, from 1st July, 1751, to 30th June, 1752. The results of his observations are contained in his memoir to the Academy of Sciences of Paris, which was communicated in the year 1755. These observations were, in all probability, taken at his residence in what is now called "Strand Street," the particular spot being marked by a tablet recently erected by the "South African Philosophical Society" to the memory of this pioneer of science in the Cape. A perusal of this most interesting paper shows him to have been a keen and accurate observer of nature, while the observations themselves prove that, so far as the Summer "South-Easter" and the Winter "North-Westers" are concerned no change whatever has taken place in our climate up to the present time.

The first systematic attempt to investigate the climate of the Cape Colony as a whole was made in the year 1860, when a Meteorological Committee was appointed by Government Notice, No. 363, dated the 26th October of that year, which ran as follows:—"His Excellency the Governor, Sir George Grey, being desirous of establishing simultaneous and systematic meteorological observations at eligible positions in the Colony, in order to obtain data on which to found measures of practical utility, has been pleased to appoint a committee of the under-mentioned gentlemen to undertake the charge and distribution on loan of the instruments purchased by Government for the purpose.

"The set of instruments for an observing position consists of a standard barometer, of a dry bulb, wet bulb, maximum, minimum, and solar radiation thermometer, and a rain gauge.

"Parties wishing to aid the Government by undertaking to make observations are requested to send in their names, address, and such information as to locality of dwelling and southern aspect of dwelling, as will guide the committee in selecting the individuals between whom the limited number of sets of instruments should be distributed. . . . A skeleton journal, ruled and headed, also directions and tables, will be furnished with each set of instruments.

"The times for reading the instruments have not yet been fixed, but it is probable that they will be 9 o'clock a.m., 1 o'clock and 7 o'clock p.m.

"Members of the Meteorological Committee:—

"The Honourable Richard Southey, Esq., Acting Colonial Secretary, Chairman.

Sir Thomas Maclear, F.R.S., Astronomer Royal.

Charles Bell, Esq., Surveyor-General.

John Scott Tucker, Esq., Colonial Engineer.

Rev. J. C. Adamson, D.D."

The first report of this committee was published in July, 1862, and contained the following introductory remarks: "Nearly half a century ago the Colonial Government showed some interest in the Meteorology of this Colony. Instructions were given to their officers in the country districts to make observations and to transmit their registers to the metropolis. Some of their returns were occasionally published. But want of attention to the individual character of the instruments and of their localities, and the consequent impossibility of applying the requisite corrections, along with the desultory character of the observations, combined to render these returns of little value to Science. In 1831, at the establishment of the South African Institution, the subject was resumed more systematically. Matters of some permanent interest are to be found in Reports issued by a committee of that body from 1831 to 1837.

"The returns of observations which were then procured by them partook of the character already noticed, so that conclusions drawn from them would not correspond to the present state or present aims of the Science. Their Reports, however, contain notices which have led to important consequences; and they indicate, in certain instances, modes of attaining results which it may be useful not to lose sight of."

The instruments mentioned above, with the exception of the Solar Radiation Thermometer, compose the equipment now supplied to all our Second Order Stations. There is, however, the very serious omission of a proper shelter for the thermometers, so that in all probability these instruments were exposed on the verandah or stoep on the south side of the house, at best a very faulty substitute for a properly constructed screen.

A very good beginning was made by distributing instruments to the following ten stations, which are fairly typical of the whole Colony: Clanwilliam, Simon's Town, Somerset West, Mossel Bay, Graaff Reinet, Colesberg, Graham's Town, and Queen's Town.

Soon afterwards was initiated the excellent plan of supplementing the data obtained from these stations by records of maximum and

minimum temperatures from what would now be termed Third Order or Climatological Stations, while the necessity for a wider distribution of rain-gauges was also realised and apparently acted upon. It will thus be seen that even at this early date there was a division of stations into the same three classes that obtain at present.

Unfortunately, in spite of this excellent start of a proper plan of campaign for investigating the climates of the Cape Colony, the enthusiasm with which the work was originally undertaken seems to have gradually declined, with the result that observations were only carried on to the year 1868, when they were dropped altogether.

In 1875 the Meteorological Committee, under its present title of the "Meteorological Commission," was resuscitated, or reorganised, under the direction of the Honourable C. Abercrombie Smith,\* who continues to hold the position of chairman; while the results of the observations which had formerly been included in the Bluebooks for the Colony, were published separately, and have been presented yearly to Parliament ever since.

Shortly after the reformation, the Commission began to realise the necessity for providing proper shelters for the exposure of thermometers, and the original small pattern of "Stevenson Screen" was adopted, with greatly improved results. In 1879, with the appointment of Mr.—now Sir David—Gill as a member of the Commission, the very important step of providing for the inspection of stations was taken, and the results showed that such a proceeding was absolutely necessary. At some stations a most ludicrous state of ignorance regarding the proper use of the various instruments was found to exist. Rain-gauges were kept inside the house, and were only put out when it was likely to rain. In one case the same instrument had been converted into a target for rifle practice; thermometers were found hung up in rooms instead of being exposed in the open air, etc. It also became evident in the course of the energetic inspections of the Secretary—first of Mr. Ellerton Fry and subsequently of Staff-Commander May, R.N. (recently deceased)—that the Siphon Barometers in use were very unsatisfactory, with the result that Sir David Gill recommended the substitution of the "Kew" pattern of Marine Barometer, with a "Vernier" scale reading to 0.002 in.

On the writer's taking up the duties of Secretary in 1897 as successor to Mr. Roland Pillans, it soon became painfully evident that, in spite of the verbal instruction given during inspection visits, the proper method of handling and reading the various instruments was but imperfectly understood by many observers, while others seemed to have no idea of how to remedy the defects to which their instruments are liable. A comparison of the barometer readings *inter se* also showed the presence of faulty instruments or inadequately trained and incapable observers. Accordingly a set of instructions for the use of "Marine Barometers" was prepared and sent to each observer. This was followed by the issue of a Meteorological Note-Book and "Register." To the latter were prefixed instructions deal-

\* Now the Honourable Sir Charles Abercrombie Smith.

ing fully with the other instruments, their defects and the means of remedying the same, and an attempt was made to encourage the study of clouds by inserting the letterpress given in the "International Cloud Atlas." As the readings of the Hygrometer were absolutely worthless in many cases, owing to incrustations of salts on the Wet Bulb the policy was adopted of supplying each observer with wick and muslin sufficient for one year.

Attention was next turned to the exposure of thermometers, as the pattern of "Stevenson Screen" then in use seemed to admit of the various thermometers being affected by both solar and terrestrial radiation. After careful consideration the improved and enlarged pattern of "Stevenson Screen," designed by Mr. Wragge, the Government Meteorologist of Queensland, was adopted. Seeing that our rain-gauges, although intended to be exposed at an elevation of four feet above ground, were fixed at different heights at different stations, plans were drawn up for the construction of a 3-foot pillar, into which the rain-gauge is inserted to such a depth that the rim or knife-edge is one foot higher. This was so designed as to admit of the rain-gauge being easily withdrawn either for examination or replacement, and has been adopted as the standard pattern. The process of withdrawing the old Siphon Barometers has been continued, with the result that the much superior Marine Barometer is now in universal use at all our Second Order Stations.

At the instigation of Dr. J. D. F. Gilchrist, Marine Biologist to the Cape Colony, a series of observations of Temperature and State of the Sea, together with investigations of the Littoral Currents by means of Drift Bottles has been entered upon, and the results for certain years have already been published. In this matter we have been indebted to the Union-Castle Steamship Company for valuable assistance, the bottles with the necessary post-cards enclosed being entrusted to the care of the captains of their mail boats going round the coast, to be set adrift at fourteen different points.

In fact, all our energies have been devoted during the last six years to improving the existing organisation so as to render it more efficient, and at the same time to bring it into line with international usage. To carry this still further, the form in which our results have been published has been gradually altered, and various additions made, until now the whole style of publication has been altered from what it was in 1896. One of the most important additions to our yearly report is the inclusion of returns from the De Beers First Order Station, the only one of its kind in all Africa, at Kenilworth, near Kimberley. This station is under the very able management of that enthusiastic meteorologist, Mr. J. R. Sutton, whose valuable contributions to the "South African Philosophical Society" have thrown a great deal of light on some of the many problems of plateau meteorology, and have at the same time removed a number of erroneous impressions derived from the discussion of previous observations.

The sum total of these labours is that there are now in operation: (a) 1 First Order Station at Kenilworth (Kimberley); (b) 1

Subsidiary First Order Station at the Royal Observatory in the Cape Peninsula, where eye observations are taken three times daily, while a Beckly Anemometer enables a continuous record of wind direction and velocity to be kept; (c) 58<sup>1</sup> Barometric Stations taking one observation per day at 8.30 a.m. (Mean Time of 30° E.); (d) 27 Thermometric Stations; (e) 418 purely Rainfall Stations (or 500 Rain-gauge Stations in all).

In addition to these, there are nine stations where the amount of Evaporation is measured, and three equipped with Sunshine Recorders, while a fourth will shortly be started in Rhodesia.

In spite of the untoward conditions prevailing in South Africa during the three years' war, it is satisfactory to be able to state that we have now the largest battery of stations since the starting of the Meteorological Commission.

It says a great deal for the enthusiasm and disinterestedness of the observers that (except in the case of Government officials) their services are purely voluntary, and carried out, on the whole, fairly well, without any remuneration other than a gift of the instruments in their possession at the conclusion of a series of five years' satisfactory observations.<sup>2</sup>

#### FINANCES.

The amount voted for Meteorology in the Cape Colony was £250 in 1875; this was increased in 1880 to £500 to provide for Inspection; about 1890 the amount voted was raised to £600.

Although the annual grant was further increased to £800 in 1899, this was only done in order to provide for the rental of office and store. The Meteorological Commission was housed till the end of 1892 in the Royal Observatory, and, as far as can be ascertained, no payment was made for the accommodation. It was then removed to the Chamber of Commerce, and subsequently to an office in town, where £60 per annum was paid in rental, and store accommodation was given free by the Public Works Department.

In 1898 office and store were removed elsewhere, when £90 per annum was paid, and since the middle of 1902 the sum of £15 per month (*i.e.*, £180 a year) has been repaid to Government for rental. It will thus be seen that while the amount of the grant has been increased by £200 above that voted in 1890, the actual increase available for meteorological purposes is the truly magnificent one of £201.

We are, therefore, practically in the same position as regards finances as we were 13 years ago, although the number of stations to be maintained has increased by about forty per cent. (40%) since then.

<sup>1</sup>At four of these, however, observations are also made at 8.30 p.m.

<sup>2</sup>The wisdom of such an arrangement is open to criticism, it would be preferable to present each observer with a new set of instruments at the end of the period and retain the old instruments, whose corrections are known, at the same place, rather than run the risk of the new instruments getting out of order during transit, with the possibility of their being in use some time before the defect can be detected and remedied.

In order that we may thoroughly realise how we stand when compared with other countries, I have extracted from the "Quarterly Journal of the Royal Meteorological Society" for 1899 the following table, drawn up by Mr. Campbell Bayard for use in his Presidential Address to that Society. Although the sum opposite the Cape Colony has been altered from £600 to £800, and a few additions made, the table remains the same in other respects.

Area, Population and Grant for Meteorology.

Country.	Area.	Population.	Grant.
	Square Miles.		£
<i>Europe—</i>			
Austro-Hungary ... ..	261,640	44,901,030	5,000
Belgium ... ..	11,373	6,586,593	2,000
British Isles ... ..	120,100	37,880,792	15,300
Denmark ... ..	14,789	2,185,335	4,300
France ... ..	204,146	38,517,975	7,300
German Empire ... ..	211,168	52,246,580	—
Greece ... ..	24,977	2,433,800	380
Italy ... ..	110,623	31,479,217	—
Netherlands ... ..	12,582	4,850,451	3,833
Portugal ... ..	35,843	4,708,178	1,783
Roumania ... ..	46,314	5,500,500	400
Russia ... ..	8,450,081	129,211,113	44,922
Spain ... ..	196,173	17,550,216	—
Sweden and Norway ... ..	299,377	7,044,568	3,900
Switzerland ... ..	15,400	2,933,334	2,200
Servia ... ..	18,050	2,162,750	1,200
<i>Asia—</i>			
Hong-Kong ... ..	30½	248,710	1,500
India and Ceylon ... ..	1,585,525	290,521,773	22,100
Japan ... ..	162,655	42,270,628	7,623
Java ... ..	718,000	34,273,561	3,000
<i>Australasia -</i>			
New South Wales ... ..	310,700	1,335,800	2,240
New Zealand ... ..	104,471	743,214	—
Queensland ... ..	668,497	484,700	1,625
South Australia ... ..	903,690	358,224	—
Tasmania ... ..	26,215	166,113	325
Victoria ... ..	87,884	1,160,484	2,300
Western Australia ... ..	975,020	171,021	3,068
<i>Africa—</i>			
Cape Colony ... ..	277,151	1,875,960	800
Mauritius ... ..	705	377,856	1,300
Natal ... ..	20,851	630,817	200
Orange River Colony ... ..	48,326	208,000	200
Transvaal ... ..	110,200	870,000	6,000
<i>America -</i>			
Canada ... ..	3,315,640	5,250,000	12,936
Mexico ... ..	751,177	10,447,974	8,600
United States ... ..	3,025,000	62,630,250	195,000
Argentine Republic ... ..	1,212,000	4,003,000	3,365
Brazil ... ..	3,218,166	17,000,000	—
Jamaica ... ..	4,193	634,491	200

The largest sum devoted to Meteorology in any country is that of £195,000 granted by the United States Government, next in order being Russia with £44,922, followed by India with £22,100, the British Isles with £15,300, and Canada with £12,936. Although no details are given regarding the German Empire as a whole, Prussia alone spends £10,750 per annum on its Meteorological Institute.

However, passing over these Great Powers, and looking at the smaller territories, we find Hong Kong, with an area of  $30\frac{1}{2}$  square miles, spending £3,000; Mauritius, with an area 1-400th that of the Cape Colony, devoting £1,300 to this work, while even Servia, with an area of about 1-15th of ours, spends £1,250.

Turning now to what is being done in South Africa, we find that Natal, with its area of 20,850 square miles, is relatively better off with its £200 than we are with our £800 to meteorologically explore an area of 277,151 square miles, although meteorology in Natal cannot be considered to be in a satisfactory condition. In the Orange River Colony the sum of £200 was voted last year to establish six Second Order Stations under the superintendence of Mr. J. Lyle, of the Grey College, Bloemfontein.

Although no sum has been specially voted for meteorological purposes in Rhodesia, there seems to be no obstacle put in the way of obtaining whatever instruments may be required. It may here be stated that this study in Rhodesia is developing rapidly under the fostering care of the Government Statist, Mr. Duthie, and of the Meteorological Committee of the Rhodesia Scientific Association. The lead in this subject, as in many others, is, however, being taken by the Transvaal Government, which has voted £6,000 for meteorological purposes, £2,000 of which are to be spent in establishing the usual Second and Third Order and Rainfall Stations, while the remaining £4,000 is to be spent on a First Order Station, equipped with continuous self recording apparatus for the accommodation of the Director of the Meteorological Department. There is also a strong possibility of the original vote of £6,000 being increased to £10,000.

It will be noticed that while all the other South African States are progressing rapidly, the Cape Colony is standing still, no provision even having been made for the re-establishment of the many stations destroyed during the late war.

Whatever outside criticism may be offered regarding this Department, it can safely be asserted that no one will venture to state that it is run on extravagant lines, especially when we consider that this is one of the most expensive British possessions to live in.

#### GENERAL REMARKS AND SUGGESTIONS.

It may seem to many that an unnecessarily long portion of this paper has been devoted to the historical aspect of the subject, and a large number of dry details mentioned which might have been

omitted, but the object that has been steadily kept in view throughout has been to demonstrate that the study of the climatology of the Cape Colony has been of no "mushroom" growth, but has undergone a slow (*very* slow, indeed) process of evolution.

It seems to me to be a standing reproach that in order to obtain anything approaching a satisfactory series of hourly observations for any place in South Africa we are compelled to depend, firstly, on the private enterprise of the much-abused De Beers Company and one of its employes; and, secondly, on the Royal Observatory, an institution maintained solely and entirely at the cost of the Imperial authorities, as represented by the Lords Commissioners of the Admiralty. Has the time not yet arrived when this Colony ought to be provided with at least one First Order Station of its own, which could be used at the same time as a Central Office for the collection and dissemination of meteorological data, and might, in addition, be equipped with self-recording instruments for the continuous study of Terrestrial Magnetism and Atmospheric Electricity, so ably initiated by Professor Morrison and Dr. Beattie? That there is nothing new or revolutionary in this idea may be gathered from the following quotation from the Presidential Address of Sir David Gill to the South African Philosophical Society on July 29th, 1881:—"I hope to see the time when two or three standard observing stations, with self-recording instruments, will be created and maintained, at least for several years, for the purpose of ascertaining the laws of the diurnal change of temperature, moisture, and pressure in various parts of the Colony." Again, the late Mr. J. G. Gamble, in his address to the same Society in the following year, states:—"We want self-registering instruments. . . . Professor Wild says that two years' observations of self-registering instruments at Berne Observatory had given more information than the previous twenty years' ordinary observations. It is as much as we can do to get two observations a day from unpaid observers, but we want readings much more frequently than that." Then, after announcing the establishment of a self-recording anemometer at the Royal Observatory, and the proposed establishment of two others at East London and Port Elizabeth, he adds: "But we want besides some self-recording barometers and thermometers, and should have at least six sets distributed throughout South Africa." More than twenty years have passed since these words were spoken, and we are still in the same condition as we were then.

The need for some such Station, or at least for some permanent office, has been very forcibly brought to my attention by the fact that during my six years' secretaryship the office of the Meteorological Commission has been situated in no less than four different places; the consequent result as regards the arrangement or rather disarrangement, of about thirty years' records can be left to your imagination, and as far as my present information goes, the time is not far distant when this office will be moved once more! As it frequently happens that past records are required as evidence in

various lawsuits, and copies of twenty or more years' observations are often asked for by other countries, etc., it is an absolute necessity that these should be housed so as to be available at any moment; while, if they are not ready to hand, their absence may not only be the indirect cause of an erroneous decision, but certainly does present a stumbling-block to the progress of many important researches undertaken by the meteorological services of other countries.

It is perhaps unnecessary to more than indicate some of the practical uses to which meteorological observations are capable of being, or have been, applied, for a just appreciation of the importance of a proper system to be realised. Among these may be mentioned Navigation, Weather Forecasts and Storm Warnings, Agriculture and Forestry—especially with regard to the possible acclimatisation of plants, trees, etc.—the study of Animal and Plant Life, particularly insect-pests, and fungoid diseases, Medical Climatology, Engineering, Irrigation, Water Supply, etc. Apart from the practical aspect, knowledge of climate is of importance to the student of national life and character, to the philologist, and even to the artist.

There is unfortunately a very common idea that the pursuit of meteorology consists of the mere accumulation of facts and figures, especially figures, so that it seems necessary to emphasise that these are only the means to an end, that end being the deduction of the laws governing the various phenomena and their causes. This, however, can only be attained by means of properly conducted investigations, which frequently require a considerable amount of time and involve a large amount of labour. Many of these may seem to be of purely theoretical interest, but it must be borne in mind that theory and practice are of mutual assistance, and the more correct the theory the more nearly perfect the practice becomes.

It is a matter for regret that the would-be investigator of the climates, etc., of the Cape Colony would meet with many annoying gaps and breaks in the records as well as an entire absence of records from many wide and important areas. It ought, therefore, to be our main object to see that the distribution of our stations is as uniform and as representative of the country as possible. To attain this end, a liberal policy in the distribution of rain-gauges to farmers and others ought to be pursued, especially in view of the important part that irrigation is likely to play in the future development of our country; many gaps in the records could be avoided by the use of the cheaper forms of self-recording instruments, Barographs, Thermographs, etc., from which the missing data could be interpolated with a reasonable degree of accuracy. A suitable distribution of the more expensive self-recording rain-gauges and anemometers ought to be carried out; these rain-gauges enable engineers to form a correct idea as to the intensity of rainfall and the probable proportion available for storage, while the anemometers would decide whether or not it were possible to employ wind as a motive force, as well as affording important information as to the direction of motion of the various storms which visit us.

It must be admitted as a rather humiliating fact that in spite of the labours of men like the late Mr. Gamble, Mr. Howard, Mr. Hutchins, and more especially of Mr. Sutton, we are compelled to go to the publications of other countries, such as Germany, England, and America, if we wish to obtain a general idea of our own climate. In fact, the best work on the Climate of Cape Colony known to me is Dr. Karl Dove's "Das Klima der Aussertropischen Südafrika," published many years ago, but which has unfortunately never been translated into English as far as I am aware. There is perhaps no country in the world where it is so important for the investigator to be thoroughly acquainted with the physiographical features of the country, to enable him to eliminate local peculiarities before proceeding to generalise. In this connection I may mention here that an investigation of the tri daily observations taken at the Royal Observatory during the years 1896-1900 has led me to very different conclusions as to the prevalent winds than those given by Dr. Buchan in the "Challenger Report."

Percentage Frequency Wind-rose constructed from Observations taken at the Royal Observatory at 8h. Noon and 20h. Local Mean Time, during the Years 1896-1900.

MONTH.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
Jan. ...	1.5	0.3	0.1	11.5	<u>52.0</u>	6.7	4.0	10.8	3.2
Feb. ...	1.5	—	0.5	8.9	<u>57.8</u>	3.4	3.7	20.6	3.6
Mar. ...	1.5	0.2	0.4	10.4	<u>48.4</u>	3.5	4.4	24.8	6.2
Apr. ...	2.8	0.6	0.6	13.1	<u>44.0</u>	3.3	3.0	22.8	8.4
May ...	6.9	0.9	0.3	12.5	<u>32.1</u>	3.4	5.1	31.5	7.3
June ...	9.4	0.9	0.3	13.6	26.3	3.0	6.7	<u>31.6</u>	8.2
July ...	<b>14.3</b>	0.8	0.2	13.1	17.8	2.5	6.5	<u>40.8</u>	4.5
Aug. ...	10.3	1.4	0.2	11.7	27.0	2.5	6.1	<u>34.3</u>	6.5
Sept. ...	5.8	0.3	0.3	12.3	<u>34.4</u>	3.3	10.1	24.9	8.4
Oct. ...	4.6	—	—	10.9	<u>39.1</u>	5.6	<b>12.6</b>	23.1	4.1
Nov. ...	3.2	0.4	0.4	10.0	<u>44.3</u>	5.1	7.3	25.6	3.8
Dec. ...	1.7	—	0.3	15.8	<u>52.5</u>	5.7	5.5	16.6	2.4
Year ...	5.3	0.5	0.3	12.0	<u>39.9</u>	4.2	6.3	26.3	5.4

Percentage Frequency of Winds, calculated from the "Challenger" data. Hours various. 18 years, 1842-55, 62-65.\*

MONTH.	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	Calm.
Jan. ...	3·2	0·0	0·0	6·4	<b>67·8</b>	3·2	6·4	12·9	—
Feb. ...	3·6	0·0	0·0	7·1	<b>64·3</b>	3·6	7·1	14·3	—
Mar. ...	3·2	0·0	3·2	6·4	<b>54·9</b>	3·2	9·7	19·3	—
Apr. ...	6·7	0·0	0·0	<b>10·0</b>	<b>46·7</b>	6·7	10·0	20·0	—
May ...	9·7	0·0	0·0	6·4	<b>41·9</b>	3·2	9·7	<b>29·3</b>	—
June ...	<b>16·7</b>	0·0	0·0	3·3	<b>30·0</b>	<b>10·0</b>	13·3	26·7	—
July ...	16·1	0·0	0·0	3·2	<b>38·7</b>	6·4	12·9	22·6	—
Aug. ...	9·7	0·0	0·0	6·4	<b>35·5</b>	6·4	16·1	25·8	—
Sept. ...	6·7	0·0	0·0	6·7	<b>40·0</b>	6·7	16·7	23·3	—
Oct. ...	6·4	0·0	0·0	3·2	<b>45·2</b>	6·4	<b>19·4</b>	19·4	—
Nov. ...	6·7	0·0	0·0	6·7	<b>56·7</b>	3·3	10·0	16·7	—
Dec. ...	3·2	0·0	0·0	9·7	<b>64·5</b>	3·2	9·7	9·7	—
Year ...	7·7	—	0·3	6·3	<b>48·8</b>	5·2	11·8	20·0	—

In both Tables the figures in heavy type indicate the maximum frequency and those in italics the minimum frequency of each wind-direction; the figures underlined show the prevailing wind-direction during each month.

A comparison of the accompanying two tables, giving the percentage frequency of the winds from the eight principal points of the compass shows that while the "Challenger" results indicate that south is the prevailing wind direction in every month of the year, the other table shows decided indications of a "monsoon" influence, in that during the winter months of June-August the prevailing direction is North-Westerly, while it is Southerly during the rest of the year. These latter results accord much more with my experience of the Cape, but a full discussion of the anemometer records would be necessary before the question could be considered satisfactorily settled. I hope, however, to develop this subject more fully at a later date elsewhere.

If any progress is to be made in solving the many problems associated with the Meteorology of South Africa, some addition to the staff of the Meteorological Commission is absolutely necessary,

\* Physics and Chemistry of the Voyage of H.M.S. Challenger: Part V., Report on Atmospheric Circulation.—By Alexander Buchan, LL.D.

as the work of collection, correction, tabulation, distribution of instruments, correspondence, etc., has increased to such an extent that it is practically impossible for myself and my assistant to overtake our daily duties, while the work of inspection has to be carried out at long intervals. I would here draw attention to the need for much more frequent inspection than can be carried out at present. It must be borne in mind that the finest instruments in the hands of unskilled and untrained observers are of far less use than inferior instruments in the hands of properly-trained men; the country is large and our stations are frequently very far apart, while the facilities for travelling are few, so that more time ought to be devoted to inspection than can possibly be the case at present.

If in the course of this address I may have seemed to speak strongly, and at times even bitterly, it is because I feel strongly the neglect to which this important subject of Meteorology has been subjected in the past. What is to be the position of the Cape Colony in regard to this subject in the future? Is it to assume the leading part that its geographical position and extent, as well as the fact of its being, so to speak, the "mother" of Meteorology in South Africa, entitles it to? Time will tell. Past experience has rendered me sceptical, but the united voice of this Association may have some effect, and "Hope springs eternal in the human breast."

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## 5.—METEOROLOGICAL RECORDS OF THE TRANSVAAL.

BY WM. CULLEN.

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### (ABSTRACT.)

Up to the present there have been very few published records of the Meteorology of the Transvaal, and those which I am putting before you now have been taken at the station attached to the Dynamite Factory, Modderfontein. The Factory itself is situated about 11 miles due north of Johannesburg, and the station adjoins the Central Research Laboratory. It would be very tedious to detail all the records, therefore only general comments will be made in the few remarks which are to follow. In order to put them in a form which can be easily grasped, a series of graphic representations have been prepared. The actual records embrace the following:—

1. Rainfall.
2. Barometric pressure.
3. Maximum temperature in the sun.
4. Maximum and Minimum temperature in the shade.
5. Actual temperature in the shade.
6. Atmospheric moisture at 6 a.m. and 12 noon, absolute.
7. Wind direction.

With regard to the first, rainfall, two graphic diagrams are appended. No. I. shows the rainfall month by month for the years 1898-1902, also for a few months of the year 1897. No. II. shows graphically, on the other hand, the number of rainy days per month over the same period. Now there is no factor so important to the agricultural community of South Africa as rainfall, and, as you see, it has an extraordinary variation up and down. The following are the records for the years 1898-1902, inclusive:—

For 1898 it was 20'10 inches.

"	1899	"	20'88
"	1900	"	26'50
"	1901	"	30'60
"	1902	"	27'63

---

25'14 Average.

---

taking the calendar year as the unit.

Of course, we know that a rain-gauge situated half a mile away might give quite different results, but over the year the figures are pretty well averaged. Speaking generally, the last three years were very much wetter than the previous two, and the diagram confirms the fact that the soldiers must have had a terribly bad time of it in the year 1901.

The diagrams are capable of many interpretations, and a careful examination of that for 1902 will show why the mealie crop is a comparative failure this year, and from a Boer point of view why horse sickness in the Transvaal has been so rampant.

Coming next to barometric pressure, we find that it is almost impossible to present records graphically, as the changes, even in the thunderstorm months, only amount to a few millimetres. In the year 1901, for instance, the highest record we have is 642 m/m and the lowest 626 m/m. The maximum is generally recorded in June. Our records are taken twice daily, *i.e.*, 6 a.m. and 12 noon, from the barometer itself, but in addition to these direct readings, we have been in the habit of taking weekly diagrams of the barometer pressure from the barograph. Naturally, the line is flat, or nearly so, but one most curious fact is brought out, *i.e.*, that the highest points are always about 10 to 11 a.m. and p.m., and the lowest about 4 a.m. and p.m. Perhaps someone who has made these records a special study can throw some light on this point.

The diagram No. III. which is appended shows the maximum and minimum barometric pressure for the years 1900-1902, inclusive.

The next series of observations for which we have records are those of temperature, and graphic diagrams in explanation are appended. They embrace the following:—

1. The average and the actual maximum temperature in the sun. The "actual" maximum temperature naturally occupies the top position.

2. The middle curves represent the average and actual maximum temperatures in the shade, and here again the actual line takes top position.

3. The lower curves indicate the actual and average minimum temperature, but here the "actual" temperature takes the lower position, as a moment's reflection will show.

It should be stated that all the readings are in Centigrade. They are recorded in rather an unusual manner. Every point plotted out on the diagram represents an actual reading, and, in order to simplify matters, the month was split up into weeks, each of six days. When there was one day over or under, it was simply included in the last week. For instance, the "actual" maximum temperature plotted out was the highest for the week, but the "average" maximum was the average of the six maximum temperatures recorded—one on each day—for the week.

Diagrams IV., IV.a, IV.b, IV.c, illustrate these records very graphically.

Needless to say, the general formation is much the same from year to year, but even a casual glance will show large differences. Taking things in their order, the greatest differences are naturally shown by the maximum temperature in the sun. In 1901, for instance, there was a sudden drop from 48° C. to 28° C., in the month of March. The lines naturally droop in the winter months, but in the year 1901 the average sun temperature rose about the same right through the year.

Another set of records, illustrated by diagrams V. and V.a, show the average temperature in the shade, and it will be observed that the readings have been taken at 6 a.m. and 12 noon.

The next set of records are those which give the absolute amount of moisture present in the atmosphere, given on the basis of grammes per cubic metre. The records were also taken twice a day, *i.e.*, 6 a.m. and 12 noon. It is difficult to say more than that during the dry season the amount in grammes is only about one-half of what it is in the wet season. The readings, as recorded by the instruments, give the moisture existing in the atmosphere at the time in percentage of possible moisture, *i.e.*, for each temperature and pressure there is a possible maximum vapour tension. During the early morning the figures are generally higher than later on in the day, and at 12 o'clock the possible is never reached except during rain.

#### AVERAGE MOISTURE IN THE AIR IN GRAMMES PER CUBIC METRE.

	1900.		1901.		1902.	
	6 a.m.	12 noon.	6 a.m.	12 noon.	6 a.m.	12 noon.
January ...	...	...	10.6	12.4	11.8	12.3
February...	...	...	11.4	12.2	11.1	12.1
March ...	...	...	10.6	11.6	10.3	11.1
April ...	...	...	9.5	9.5	7.8	8.8
May ...	...	...	6.6	5.9	6.9	7.3
June ...	4.1	5.2	6.1	5.6	4.8	5.4
July ...	5.4	5.6	4.2	4.1	5.3	6.0
August ...	4.3	4.9	5.4	5.1	5.4	6.2
September ...	5.3	6.6	6.7	6.4	6.9	7.8
October ...	7.6	8.3	7.9	7.8	7.8	9.1
November ...	9.4	10.8	9.9	11.0	9.6	10.2
December ...	9.3	11.9	11.2	11.9	10.7	12.6

These records are merely the average of the weekly averages, which are obtained in the same manner as already described.

It is most interesting to compare these records with the rainfall, and, going still further, to observe the effect of rainfall on the temperature, for there is always a sudden drop in temperature after a rainfall, and these drops are brought out very graphically by the thermograph diagram. Naturally, it is impossible to have all these records mentally before one, therefore a few diagrams are attached illustrating the point. Generally speaking, the amount stated in grammes per cubic metre is about 4.6 grammes in the dry season and double this amount in the wet season, and a glance through the average figures month by month and year by year gives a fair indication of the season with regard to the rainfall.

The amounts for the months of June, July and August of 1902 come to 55 grammes, and for December, 105 grammes. In January of the same year we had a maximum percentage of moisture on two days only, at 6 a.m. and noon, and on both of these days we had heavy rains. Speaking generally, the records taken at 6 a.m. show that the atmosphere contains about 75% of its possible moisture, while at noon it is only about 50%.

Some interesting facts are brought out by examination of the following summary of the records of wind direction, but in explanation it ought to be stated that the records for 1897 only embrace the last three months of the year. Further, that as two readings were taken daily, the total readings for the year or month are just exactly double the number of days in the year or month.

	N.	N.E.	N.W.	E.	W.	S.	S.E.	S.W.
<b>1897</b>								
Total ...	33	59	67	5	7	2	1	2
Average (per month)...	11	19.6	22.3	1.7	2.3	.6	.3	.7
<b>1898</b>								
Total ...	143	181	72	105	24	60	78	63
Average ...	11.9	15.1	6	8.8	2	5	6.5	5.2
<b>1899</b>								
Total ...	130	255	78	122	22	20	60	43
Average ...	10.8	21.1	6.5	10.2	1.8	1.7	5	3.6
<b>1900</b>								
Total ...	82	271	147	46	0	11	74	90
Average ...	6.8	22.6	12.2	3.8	.7	.9	6.2	7.5
<b>1901-</b>								
Total ...	36	282	140	14	13	4	140	75
Average ...	3	23.5	11.8	1.2	1.1	.3	11.2	6
<b>1902</b>								
Total ...	87	270	111	30	20	8	83	106
Average ...	7.2	22.5	9.2	2.5	1.7	.7	7	8.8
Grand Total ...	511	1318	615	322	95	105	436	379
Grand Average ...	7.1	20.9	9.8	5.1	1.5	1.7	7.1	6.0

As will be seen, the prevailing winds are all from the North or East.

In explanation of the diagram, it should be said that the figures in the different columns represent readings, and as there are always two for each day, the total for the month will be twice the number of days. There is nothing particular to be said with regard to wind velocities, but the records will be published later on, and will be available for those who care to study them. Indeed, the same remark applies to all the detailed records, and when they are carefully studied with other and known data, they will repay the trouble.

#### DIAGRAMS.

Diagram I.—Rainfall from October, 1897, to December, 1902.

Diagram II.—Number of rainy days from October, 1897, to December, 1902.

Diagram III.—Maximum and minimum barometric readings for 1900, 1901 and 1902.

Diagram IV.—Temperature records for 1899. (Maximum and Minimum.)

Diagram IVa.—Temperature records for 1900. (Maximum and Minimum.)

Diagram IVb.—Temperature records for 1901. (Maximum and Minimum.)

Diagram IVc.—Temperature records for 1902. (Maximum and Minimum.)

Diagram V.—Average temperature in the shade for 1901.

Diagram Va.—Average temperature in the shade for 1902.

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# NUMBER OF RAINY DAYS

I.

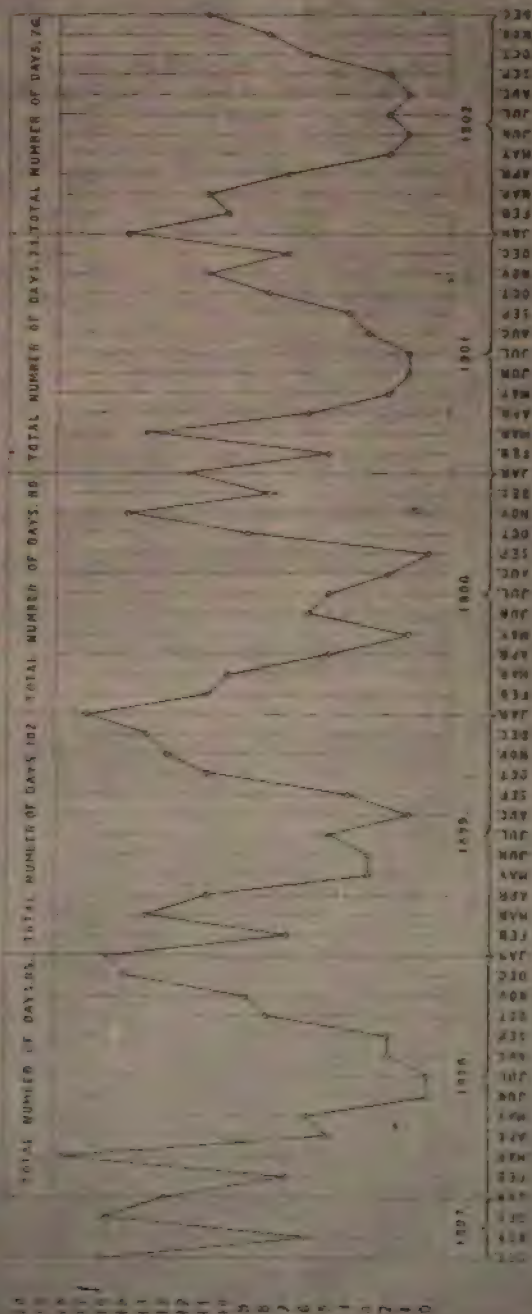


DIAGRAM L. RAINFALL FROM OCTOBER, 1897, TO DECEMBER, 1902.

# RAINFALL 2

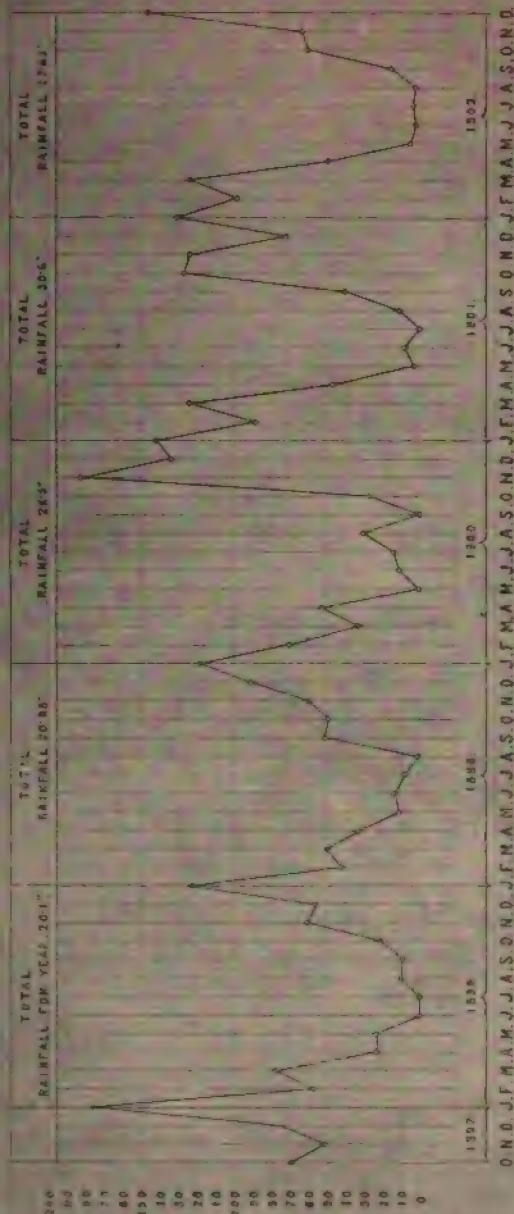


DIAGRAM II. NUMBER OF RAINY DAYS FROM OCTOBER, 1897, TO DECEMBER, 1902.

# ACTUAL MAX. & MIN. BAROMETRIC PRESSURE.

3.

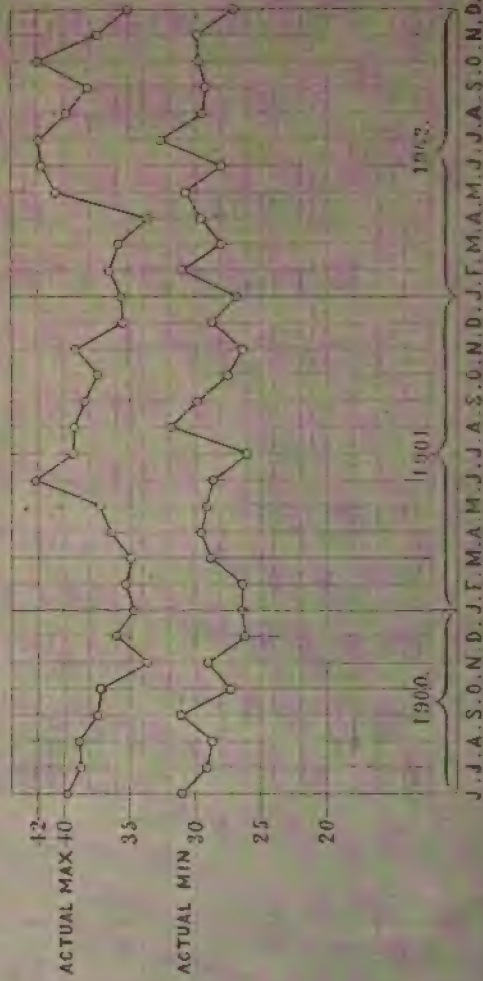


DIAGRAM III.—MAXIMUM AND MINIMUM BAROMETRIC READINGS FOR 1900, 1901, AND 1902.

TEMPERATURE RECORDS

1899

4.

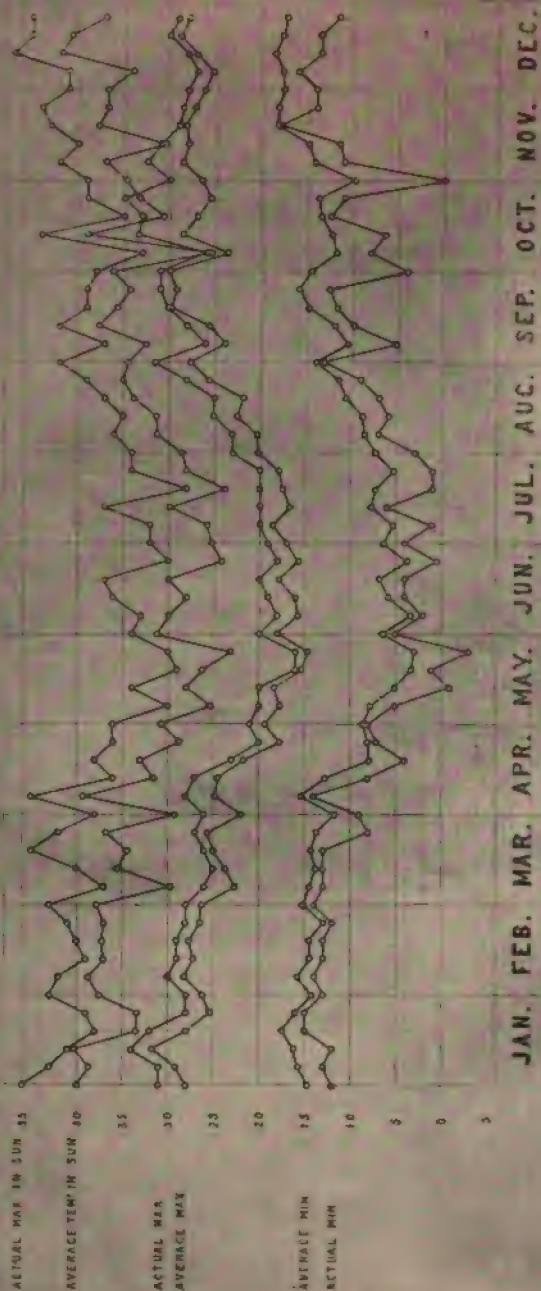


DIAGRAM IV.—TEMPERATURE RECORDS FOR 1889. (MAXIMUM AND MINIMUM.)

## TEMPERATURE RECORDS

1900

4A.

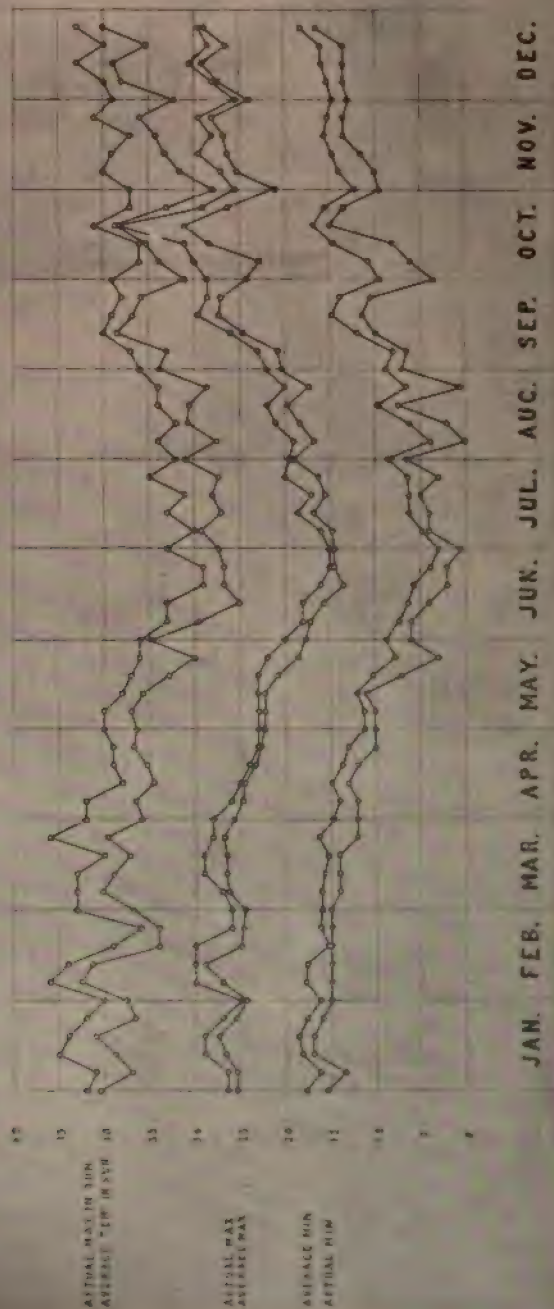


DIAGRAM IVd.—TEMPERATURE RECORDS FOR 1900. (MAXIMUM AND MINIMUM.)

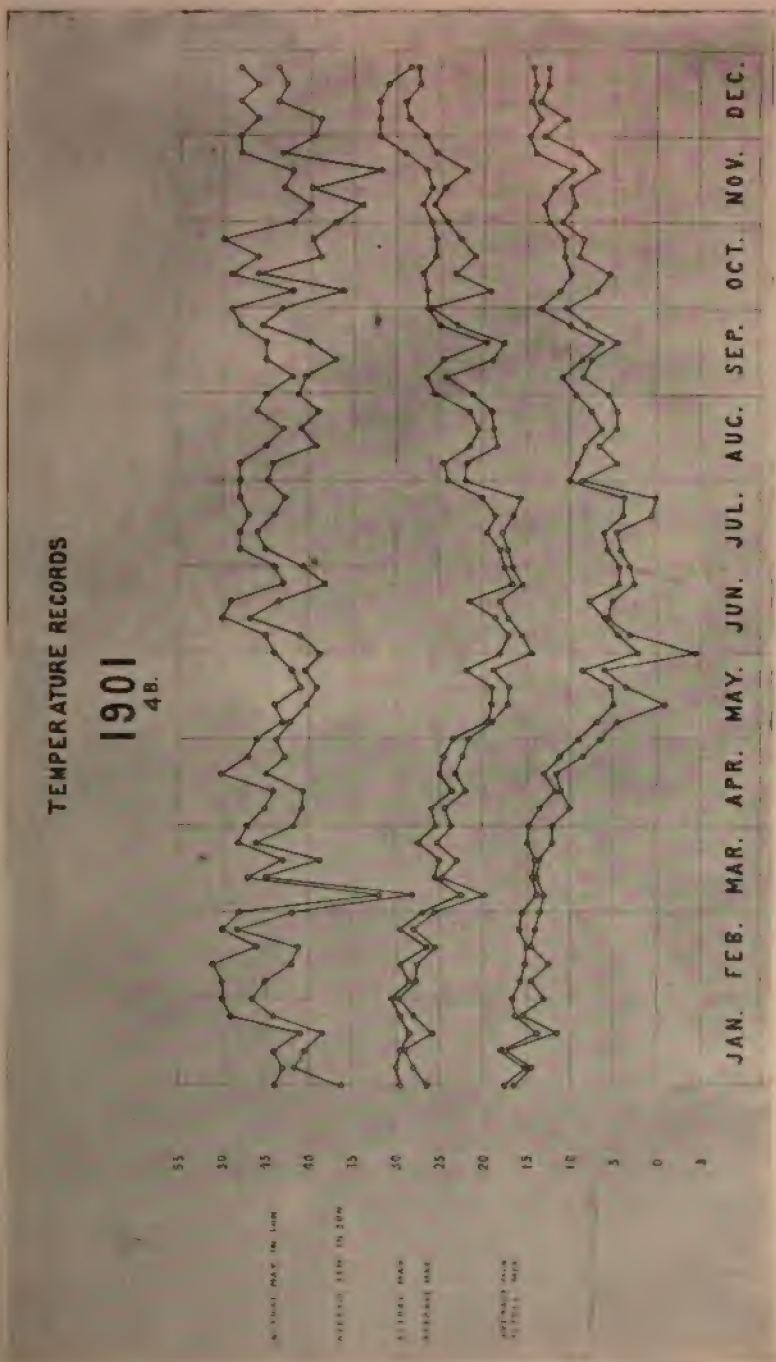


DIAGRAM IVb.—TEMPERATURE RECORDS FOR 1901. (MAXIMUM AND MINIMUM.)

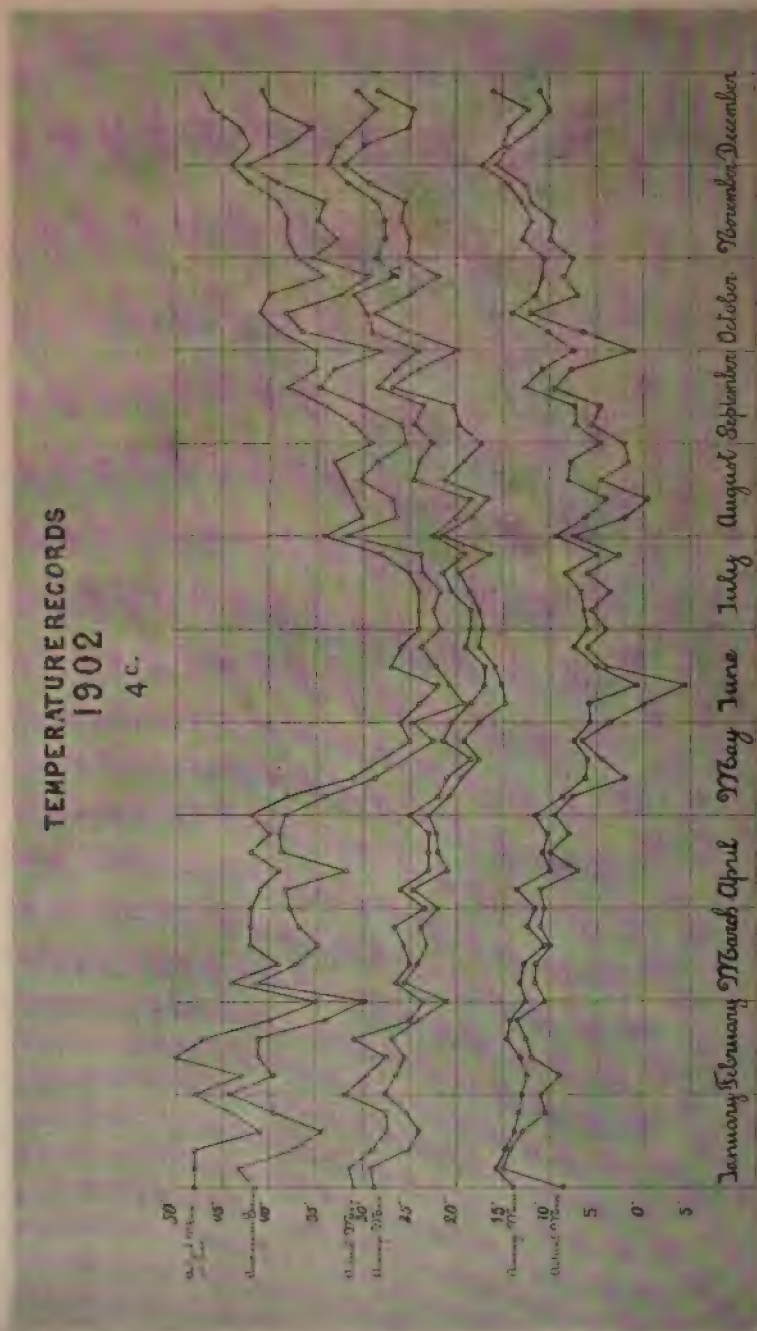


DIAGRAM IV.—TEMPERATURE RECORDS FOR 1902. (MAXIMUM AND MINIMUM.)

AVERAGE TEMPERATURE IN SHADE

1901  
5

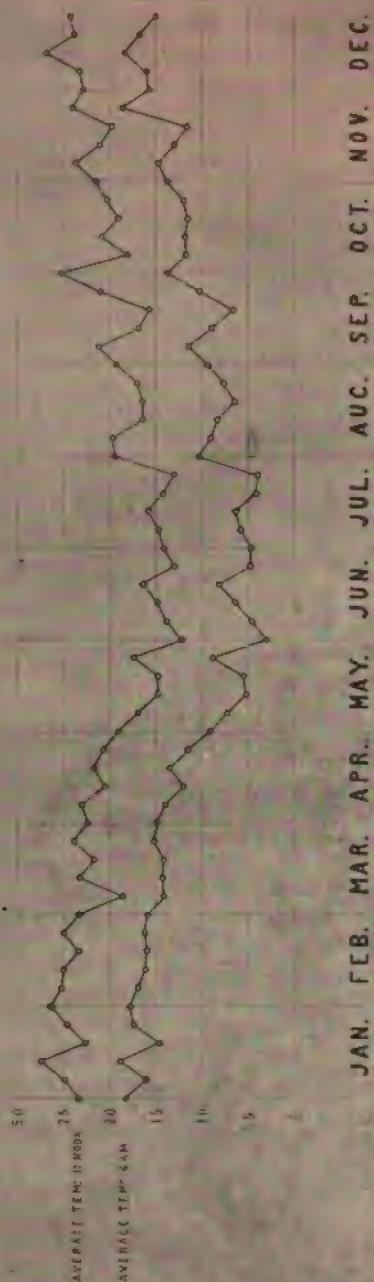


DIAGRAM V.—AVERAGE TEMPERATURE IN THE SHADE FOR 1901.

## AVERAGE TEMPERATURE IN THE SHADE

1902

5A.

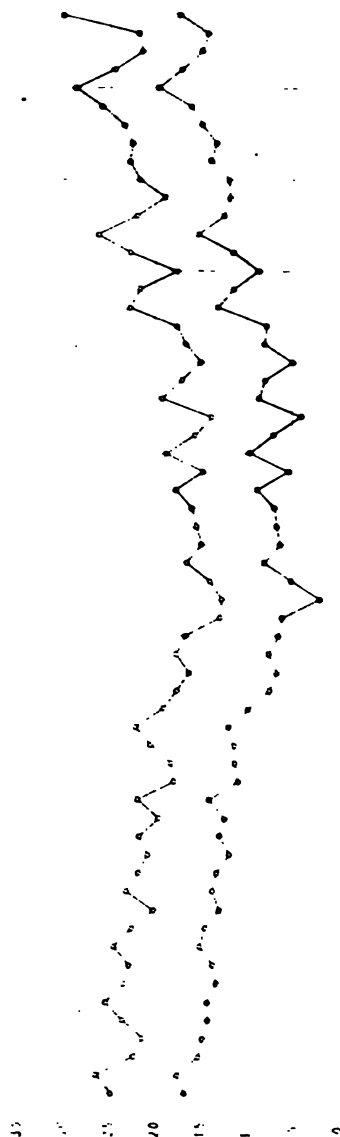


DIAGRAM V6,--AVERAGE TEMPERATURE IN THE SHADE FOR 1902.

## 6.—NITRO-GLYCERINE EXPLOSIVES: THEIR INFLUENCE ON INDUSTRIAL DEVELOPMENT.

By WM. CULLEN.

The field of explosives, at least to those who are actively concerned in their manufacture, is a very wide one, and for this reason, among others, I have limited myself to some remarks on the *nitro-glycerine* class of explosives. In one sense only is it a limitation, as all the important developments in the explosives world have been intimately concerned *with* nitro-glycerine. Perhaps the most important reason of all for the limitation referred to is the fact that here in South Africa we hardly ever hear of anything else, and there is nowhere in the whole world where such an industrial transformation has been effected, indirectly, through explosives; but without them, all the same, there could have been no such development.

In the remarks which are to follow, I intend, in the first instance, to say a little about the historical part of the subject, pointing out the principal steps which have led up to the development of the explosives, as we know them now. Next, I shall briefly outline the manufacture, illustrating it by a few magic-lantern views, and lastly, but only briefly, I shall deal with the industrial aspect of the question, with special reference to South Africa.

Nitro-glycerine has only been known for a comparatively short time, a young Italian, named Sobrero, having discovered it in 1846. Some time elapsed before we hear of it in any other application than that of medicine, and even to this day it is prescribed for a certain heart affection. Indeed, no advantage was taken of its explosive properties till the Swedish Chemist, Alfred Nobel, commenced his investigations in the year 1863, and he was not long in discovering its tremendous potentialities. In a few years, we hear of factories being established all over Europe and America, and, as in the case of every new invention, the appliances used at first were extremely primitive. Some of these primitive appliances survived until comparatively recent times, and it will suffice for our present purpose if I say that, for the most part, the manufacture, if manufacture it could be called, was carried on in much the same manner as we would carry it on nowadays in the Laboratory. In the days of which I speak people were content to convert one or two pounds of glycerine into nitro-glycerine; nowadays, we start with half a ton of glycerine, and from it produce over a ton of nitro-glycerine.

It seemed that there was a great future for nitro-glycerine, for it was universally used for blasting, as liquid nitro-glycerine, all over Europe and America, but in a very short time there came a rude awakening. Nowadays, one is frequently surprised at the careless manner in which explosives of all kinds are handled by people who

ought to know better, and even with regulations of the very strictest order governing both manufacture and use, serious accidents are not infrequent. Forty years ago these regulations were practically a dead letter, and people were ignorant of what nitro-glycerine was capable of doing. As I have just said, there came a rude awakening, and a series of most disastrous accidents followed one another in rapid succession. I cannot do better than quote from "Chemistry, as Applied to the Arts and Manufactures," Div. VI., pp. 435-6:—

"The highly-favourable reports on the explosive value of nitro-glycerine were soon followed by statements of its being one of the most dangerous of known blasting agents. In 1866, a West India Mail Packet was blown up, a wharf torn down, a number of adjacent ships were injured, and many lives lost at Colon through an explosion of nitro-glycerine. Not long after that, a fearful accident happened at San Francisco, by the dropping of a box containing the same material. Later on, a Newcastle Magistrate and several other persons fell victims to an accident with this same explosive body. In 1868, a factory at Stockholm, where nitro-glycerine is manufactured, was blown up, and a number of men killed, and not long after that an explosion, attended with fearful loss of life, occurred in Belgium. This last-named accident led to the authorities altogether prohibiting the use of this explosive compound in that kingdom."

In view of all these disasters, it appeared that nitro-glycerine was doomed as an explosive, and in 1874 a Select Committee, which had been appointed to investigate the matter, issued its report, and the conclusion at which it arrived was very pithily put by Sir Frederick Abel, in a letter addressed to Sir John Hay, who, if I am not mistaken, was Chairman of the Commission. He writes:—

"In reply to your enquiries respecting nitro-glycerine, the production and properties of which have been made the subject of careful study and extensive experiments by me, I have to express my firm conviction that such appalling accidents as that which occurred recently in Wales cannot be guarded against by the enforcement of any means short of an absolute prohibition of the importation, transport and storage of nitro-glycerine, or of any preparation of that material. The explosion near Carnarvon was but a repetition of catastrophes of a similar nature which have occurred within the last few years in other countries, and are ascribable to the readiness with which nitro-glycerine explodes, when subjected to concussion or friction, especially if it is undergoing spontaneous change, to which it is very prone, however perfect the system of manufacture."

The recommendation made by Sir Frederick was drastic enough in all conscience, but it was the only possible one, and it was adopted, so the transportation, storage and use of nitro-glycerine, as such, were entirely prohibited in the United Kingdom.

I may say that it had been the custom to send it about in ordinary tins, which, of course, could not stand much knocking about, and many of the accidents occurred through the breakage

of these tins. In America an ingenious scheme was adopted to get over some of these difficulties, viz., the transport of the nitro-glycerine in frozen blocks—for at about  $12^{\circ}\text{C}$ . it freezes into a solid mass, which can hardly be distinguished from ice. However, as several of you who are sitting here know well, frozen nitro-glycerine is not one of the most pleasant things in the explosive line to handle, and this expedient had likewise to be abandoned. I understand that until quite recently nitro-glycerine as such was used rather extensively in railway work in America, and it was quite common for the men who were skilled in hand making nitro-glycerine to follow up a contractor, making the nitro-glycerine as he went along, and naturally it was consumed on the premises, the waste acids being simply thrown away. Nowadays, we have to be a little more economical.

One would have thought that the experiences just related would have been sufficient to daunt the most intrepid, but Nobel never really abandoned his experiments. One of the expedients which he tried to make nitro-glycerine safe for transport met with a fair amount of success at the time, but it in turn had to be abandoned. It was to mix the nitro-glycerine with methyl alcohol, and transport it as a mixture. When it was required for use the methyl alcohol was simply washed out by water.

Time does not permit of my following Nobel through all his experiments, suffice it to say that his attention was next directed to finding some porous body in which the nitro-glycerine might be absorbed. After hundreds of experiments, he finally fixed on Kieselguhr, and in the year 1867 this explosive was introduced under the name of Dynamite, which name it bears to this day.

Although many people tried to circumvent this invention by the use of other absorbents, no one has ever succeeded in improving on the Dynamite of 1867, which is identical with the Dynamite of 1903. I do not use the name in its general sense, as we all do in South Africa, but as the name of a certain explosive. This discovery marked, perhaps, the most important point in the development of nitro-glycerine explosives.

About this same time an English chemist, attached to the War Office, had been experimenting with fulminate of mercury, with the object of finding out whether a cap could not be devised for setting off explosives in much the same way as caps had been used up to that time for the muzzle-loading guns, the only kind then in use. Fulminate itself was actually discovered in 1799, and the first caps were made by an English gunmaker 16 years later. The only explosive used until the discovery of nitro-glycerine, and subsequently of Dynamite, was the well-known Black Powder, which was then, and is still, ignited by means of the ordinary fuse, which every one knows so well. This fuse, however, was not so suitable for the newer kind of explosives, but the chemist referred to just now was successful in devising what was nothing more nor less than a large cap, which when used in conjunction with the ordinary fuse imparted quite a different effect to Dynamite, so that it (the Dynamite)

rapidly came into universal use; it would never have done so without detonators.

The introduction of detonators undoubtedly marks another very important advance in the development of explosives.

We can safely assert that about this time, *i.e.*, the year 1870, only two kinds of explosives were known, *viz.*, Black Powder and Dynamite, and even to this day nothing has superseded these explosives for certain classes of work. Dynamite was considered a safe, a reliable, and a powerful explosive, and so it is, but Nobel was quick to recognise that it had its weak points. One of these was that as an explosive it was ballasted with about 25 per cent. of an absolutely inert body, and another, and perhaps the most important in his mind, was the fact that it was not very well suited for wet workings. As a matter of fact, Dynamite, when steeped in water, parts with its nitro-glycerine, and to a more limited extent the same thing takes place when it becomes moist. This phenomenon we generally call exudation.

Nobel's name is again associated with the next important advance in the technology of explosives, and it is a testimony to the man's genius, to his far-sightedness, that after 27 years' experience, the explosives made and used in the South African Gold Fields are with paltry exceptions according to his original patent specifications.

The point he desired to attain, and the point he did attain, in his Blasting Gelatine specification of 1875 was to make the entire compound explosive, and not only a part of it as in the case of Dynamite. The purpose of his invention is set out in the following extract from the patent itself:—"The purpose of the invention is to convert liquid explosive substances, such as nitro-glycerine, or nitrates of methyl, ethyl and amyl, and nitro-benzine into a viscid or pasty state." Later on he says:—"In carrying out the invention, these liquid explosive substances are incorporated with another substance, which is capable of gelatinising or thickening them, and for this purpose a substance is chosen which will detract little or nothing from the explosive power."

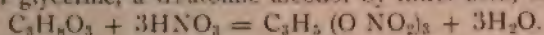
As an example of this he instances nitrated cotton, which is known as Collodion Gun-Cotton.

This body dissolves in nitro-glycerine with more or less readiness, and produces a doughy mass, of which more anon.

From this point I must leave the domain of history. Indeed, no important discovery has been made within the past fifteen years, excepting the extraordinary developments in modern smokeless powders, and strangely again, Nobel's name is also associated with that discovery. Later on I shall refer very briefly to this important discovery.

It is necessary now to say something about the body, nitro-glycerine, itself, but fortunately this need not detain us very long. I have prepared a few magic lantern views to illustrate the processes of manufacture, but think it better to defer them to the end of the paper, adding a few explanatory words as each view is put on the screen. Nitro-glycerine is not really a nitro body in the

chemical sense of the term, but a nitrate being formed through the nitration of glycerine, a tri-atomic alcohol by nitric acid, so



In fact, the formation of nitro-glycerine takes place by means of a very simple, straightforward chemical equation, and the elementary analysis of the product agrees perfectly with the above formula. The preparation of nitro-glycerine is really a most simple operation—when everything goes right—but like every other simple operation there is a right and a wrong way of doing it. The knowledge of how to do it the right way constitutes a man an expert. From the equation, which I have just shown you, it would appear that all one has to do is to mix glycerine with nitric acid, and chemistry, that very vague thing, does the rest.

But long before the stage just referred to has been reached, many things have to be done, and many chemical equations would require to be put on the black board to explain them. First of all, we must have very pure anhydrous glycerine, and the manufacture of this article involves some highly complicated processes, and the use of some of the most beautiful machinery which can be seen in any branch of applied chemistry. Few manufacturers make their own glycerine, but many buy it in the crude state, and then refine it. It is in the main a bye-product from soap and candle making, and manufacturers of explosives as a rule find they have quite enough to do without meddling with other industries. Then we must have our nitric and our sulphuric acid, both as strong and as pure as it is possible to make them. I have already said that there are tricks connected with every manufacture. Sulphuric acid did not figure in the equation which I have just given you, yet for reasons which I shall explain, its presence is absolutely necessary.

The manufacture of sulphuric acid, although one of the oldest of our chemical industries, is still a very complicated one, but I take it that most people have a fair idea of how it is done. At the Modderfontein Factory, with which I am connected, we are at present using the old process commonly called the chamber process, but we hope soon to have the modern or contact process installed. It is unfortunate that up to now we have discovered nothing in the whole of South Africa which can take the place of the Sicilian sulphur which we burn in our ovens; but the new process will, we trust, allow us to work the low grade pyrites which is so abundant on the Rand. As will be seen from the views which will presently appear on the screen, our plant is a very large one, indeed, among the largest in the world; but the addition of the contact plant will make it almost the largest.

I cannot pass this part of the paper without commenting on the fact that the process to which I have just referred has been known since ever books on chemistry were written, and yet only within the past few years, and principally by the aid of engineering as applied to chemistry, it has come to the front, and will completely revolutionise our oldest and most important chemical industry. The same remark applies to many other processes, until

some one whose eyes are not blinded by routine comes along, sees the practical application, and applies it accordingly. A parallel case is that of the extraction of gold by means of cyanide, an experiment which thousands have carried out years and years ago. McArthur was far-seeing, and applied it in a way which has been of incalculable benefit to South Africa, but not much good to himself.

The chamber process for making sulphuric acid is roughly as follows:—Sulphur or pyrites is burned in ovens, and  $\text{SO}_2$  is produced. This gas is carried into large lead chambers, together with some oxides of nitrogen. Water is also injected as steam. The nitrogen oxide being what we call an oxidising body hands over part of its oxygen to the  $\text{SO}_2$ , producing  $\text{SO}_3$ , which in turn combines with the water present, forming sulphuric acid, of a diluted kind, called chamber acid. This has to be concentrated up till it contains 96%  $\text{H}_2\text{SO}_4$ , and, among other things, I may mention that our platinum stills for this purpose represent a value of £100,000. The contact process aims at producing strong acid right away, thus saving all the cost of concentration. Sulphur or pyrites, as in the chamber process, is burned in ovens, and the  $\text{SO}_2$  produced, together with atmospheric oxygen, is passed over a catalytic agent—generally finely divided platinum—which causes them to combine, forming  $\text{SO}_3$ . The necessary amount of water can be added in many ways, but in any case strong acid is produced right off.

This also sounds simple, but the working out of the process to its present state of perfection has involved years of most patient research, and it is perhaps the best example extant of the mutual inter-dependence of the engineer and the chemist.

I have started with sulphuric acid, for it is required in order to make nitric acid, which is also a simple operation, chemically speaking, but which in recent years has become entirely revolutionised by modern improvements. Nitric acid, as you know, is made by distilling a mixture of nitrate of soda and sulphuric acid. It is unfortunate that up to now the only deposit of nitrate of soda of any commercial importance is the world renowned one in Chili, from which all manufacturers of explosives have to draw their supplies.

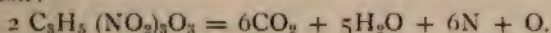
Now that we have seen to our raw materials, we can start away on the manufacture of nitro-glycerine. Sulphuric and nitric acids are first of all mixed roughly in the proportion of two of the former to one of the latter, and when this is done, glycerine is dropped or sprayed into the mixture. A large amount of heat is evolved, and in order to keep down the temperature, cold water is constantly kept circulating through coils in the body of the apparatus. I have already said that the acids must be as strong as possible, and the sulphuric acid is present only to take up the water formed in the reaction. Not so very long ago the amount of glycerine used in each charge or operation was comparatively small, but nowadays about a long ton of nitro-glycerine is made at one charge. About 220 parts of nitro-glycerine are obtained from every 100 parts of glycerine. I need not take you through all the side processes, as

I shall refer to them in some detail when the views are on the screen, but now I need only say that these processes involve:—

1. The separation of the nitro-glycerine from the acids.
2. The separation of the acids from the nitro-glycerine.
3. The purification of the nitro-glycerine.
4. The recovery of the waste acids, and many others of lesser importance.

Nitro-glycerine is a heavy oily liquid of 1·6 S.G., having as a rule a straw yellow colour, but when made from perfectly bleached glycerine and nitric acid, it is almost water white. It freezes about 12°C., and the sp.gr. of the frozen body rises to 1·735 (Guttmann). This peculiarity of freezing has led to more accidents in Europe than all other causes combined. Fortunately, we do not often see frozen nitro-glycerine explosives in South Africa. It has a slight vapour tension, and a peculiar smell. Nobel informed me some years ago before his death, that he had at one time distilled 1 cwt. of nitro-glycerine under reduced pressure, which merely illustrates the fearlessness of the man. If perfectly purified and freed from acids it will keep for an indefinite period, and I have seen samples 20 years old. On the other hand, it sometimes takes it into its head to decompose for no apparent cause, but I am convinced that in every case this is the result of faulty manufacture. It is not necessary to say anything about its sensitiveness to shock, as in general terms this fact is fairly well known.

When decomposed in a confined space it is resolved into carbonic acid, water, nitrogen, and oxygen, according to the following equation:—



so that it has in itself more than sufficient oxygen to burn up all the elementary constituents. This is a most important point. Every litre of nitro-glycerine equivalent to 1·6 kilos by weight produce 1·141 litres of gas, a truly enormous quantity, the volume being reckoned at 0°C and 760 m. pressure. The water is also calculated as in the gaseous state. The theoretical temperature at explosion is 6980°C., and as the mechanical work is the function of the gas volume by the temperature, one can readily realise how it is that nothing else approaches it in power. The pressure exerted at the theoretical temperature is 20,000 kilos per sq. centimetre, or, roughly, about 1,300 tons per sq. inch. Taking equivalent volumes of black powder and nitro-glycerine, the latter produces an explosion, a pressure 10 to 12 times as great as ordinary black powder, and the actual work calculated weight for weight is roughly as three to one.

I have said quite enough about nitro-glycerine to show you—as indeed requires no demonstration—the enormous potential energy it possesses. I am almost tempted at this point to discuss some matters which relate more to the domain of theory and scientific research, but time does not permit, and I shall therefore continue to look at the subject from its everyday practical aspect.

I have referred incidentally to two nitro-glycerine explosives

already, viz., Dynamite and Blasting Gelatine, and it so happens that these are the best known types of two widely differing classes. Dynamite, that is Kieselguhr Dynamite, the explosive almost exclusively used in the Diamond Fields at Kimberley, is the best known example of a class, the chief aim of which is to absorb the nitro-glycerine in some absorbent or semi-absorbent body. There are endless varieties of this class, but in Europe they are not manufactured to any extent. It is, however, otherwise in America, where the nitro-glycerine explosives are almost entirely of this type. Most of them are mixtures of nitro-glycerine with wood-meal or pulp, nitrate of soda, and one of several other ingredients, the presence of which is sometimes rather difficult to explain.

The nitrate is, of course, added for the purpose of oxidising the organic absorbent, but it is quite evident that in every one there is bound to be a large amount of mineral matter, which is utterly useless as an explosive; not only so, but a proportion of the heat developed is lost in heating up this mineral matter, and in the case of Kieselguhr Dynamite, which has 25% of an absolutely inactive body, the loss of heat must be and actually is very considerable. Nearly all the explosives of this class are powdery or semi-powdery, but Dynamite is semi-plastic.

The second class includes all the gelatinous explosives, and here they go by the familiar names of Blasting Gelatine, Gelatine Dynamite, and so on. They (the latter) are, however, all only lower grades of Blasting Gelatine.

It does not come within the province of this paper to discuss the relative merits of what I might call the American type, as against the gelatinous type, and there is plenty to be said on both sides of the question, and no doubt there are certain classes of work for which each is in its way best suited. Rather would I take these two types, and say a few words about their manufacture and properties, illustrating later on by means of the lantern how the actual working is carried on.

Dynamite is now going sadly out of fashion, as can be seen from the returns, imports and exports, published by our various Colonies. In the Transvaal, which is the largest market for explosives in the world, the sales only form a little over 1% of the total. Its manufacture is extremely simple. Kieselguhr, the absorbent body, is found in many parts of the world, and is simply a conglomeration of most minute shells of tiny animalculae (Diatome). Under the microscope they are seen to have a very delicate structure, but there is no evidence of this to the eye in the earth as found. Chemically, it is almost pure silica, and the reddish colour which it generally has, and which is more marked when made into Dynamite, comes from traces of oxide of iron. It is necessary to free it from organic matter and moisture, a simple kiln roasting generally sufficing for this purpose. It is next ground to an impalpable powder, and naturally gritty matter has to be most carefully removed. When this stage is reached the nitro-glycerine is simply mixed with it by hand, and then sifted several times to ensure thorough mixing.

Some qualities of Kieselguhr will absorb as much as 80% nitro-glycerine, but about 75% is the average, and this is the proportion in which it is generally manufactured.

Nitro-glycerine, as I have already mentioned, freezes at about  $12^{\circ}\text{C.}$ , and all explosives containing it are affected the same way. When Dynamite freezes it is converted into a hard stony mass, and to get the same explosive effect, as from unfrozen, a detonator three times as strong as the usual must be used. It is very dangerous to ram frozen Dynamite into a bore-hole, and it should always be thawed before use, but many accidents happen through the careless performance of this simple operation. At Parma, in 1878, a cavalry lieutenant killed and wounded 80 people by neglecting ordinary precautions in thawing a little over 2 lbs. of Dynamite. I have already referred to its one great drawback, viz., the displacement of the nitro-glycerine when it comes into contact with water, and this as much as anything has led to its gradual extinction. In its favour, however, it must be stated that it requires a much more violent shock than nitro-glycerine to explode it, and it is not nearly so shattering, the explanation being that a part of the initial heat of combustion is absorbed in heating up the Kieselguhr, thus reducing the initial pressure.

So much then for Dynamite, and now I shall say a few words about Blasting Gelatine, which is from the scientific as well as from the technical point of view, a much more interesting body in every way. I have already outlined how Nobel first came to think of substituting the Kieselguhr of Dynamite by a body actually explosive in itself. The result was the most powerful explosive which has ever yet been made or ever is likely to be made. Nitro-cellulose had been known and used for various purposes long before Nobel brought out his Blasting Gelatine, and about 1860 the Austrian Government actually went to the length of deciding to adopt one form of it called Gun Cotton for small arms and field guns. Terrible accidents in Austria, as also in England, however, put a complete stop to these projects, but, as I have already remarked, it took a good deal of danger to daunt Nobel. Another form of nitro-cellulose, generally known as Collodion Cotton, has come into great use, in photography principally, in the production of wet plates. Nobel found that this Collodion Cotton was soluble in nitro-glycerine, which in consequence became thickened or gelatinous. The method of producing a nitro-cellulose suitable for the manufacture of a good Blasting Gelatine is a secret very jealously guarded by manufacturers, and although it is now 25 years since Nobel filed his patent, there is still something to learn. The chemistry of nitro-cellulose belongs to that branch which we call obscure, but the point which all manufacturers seek to arrive at in practice is to use as little nitro-cellulose as possible in their Blasting Gelatine. It would serve no useful purpose to inquire into the reasons for this, but I would only say that the health of the miner and immunity from accidents depend to a great extent on a + 2% of nitro-cellulose, and that the gelatinous explosive which has the minimum of nitro-

cellulose is always the best, other things being satisfactory. We shall, therefore, start by assuming that we have an excellent nitro-cellulose, the test of its excellence being its capacity to convert nitro-glycerine into a doughy mass with the minimum quantity. The manufacture of this nitro-cellulose is a most ticklish matter, the ultimate quality depending on so many different things, among which I may cite the source of the raw cotton, the extent to which it has been washed or bleached, *i.e.*, converted into oxycellulose, or other quasi-cellulose, the strength of the acids, the temperature of nitration, the method of washing, and a host of other details. However, it is possible to produce a good nitro-cellulose which is entirely soluble in nitro-glycerine. Other nitro-celluloses higher in the scale of nitration, such as gun cotton, are almost completely insoluble in nitro-glycerine, and some of them much lower are equally insoluble. When nitro-cellulose in the shape of pulp is mixed with nitro-glycerine in the heat, it dissolves very rapidly, and if the process of solution be further continued in a machine something like a bread-kneading machine, what we call the maximum gelatinising effect is produced, and the result is a plastic dough which has only to be pressed through a sausage machine in order to make cartridges. It does not take much imagination to understand how different sizes of nozzles or dies will produce different diameters of cartridges, and this is really how the different sizes are produced. A good Blasting Gelatine ought not to contain more than 8.25% nitro-cellulose, and as will be seen from the dummy specimen exhibited, it is a pliable, rubbery mass, having generally a yellowish milky white appearance. The milkiness comes from small globules of air imprisoned throughout the mass, but after a few months' storage these disappear, and the body becomes amber-coloured and quite transparent.

This plasticity makes Blasting Gelatine one of the safest explosives to handle, and if statistics be carefully examined, they will reveal the fact that in the hands of the experienced people who manufacture it, an accident is a very rare occurrence. For this same reason it is calculated that the initial shock necessary to explode Blasting Gelatine is six times as great as that for Dynamite. Blasting Gelatine is, therefore, comparatively insensitive to explosion by influence, and some years ago, when the ambition of every artillerist was to throw the biggest projectile the longest distance with the greatest effect, the now forgotten Zulinsky Gun, the invention of a very clever American, made its appearance. It did do all, or nearly all, that its inventor claimed for it, and threw a large projectile with an equally large charge of Blasting Gelatine very long distances, but for reasons which we need not discuss the idea has now been finally abandoned. Another excellent property of Blasting Gelatine is the fact that it suffers practically no deterioration from contact with water. In fact, it can be used in wet and dry holes with equal facility, and it can be stored under water for an indefinite period.

The theoretical pressure developed on explosion is much the same as in nitro-glycerine. One might fairly expect it to be higher,

as the volume of gases is slightly higher, but the temperature, on the other hand, slightly lower. Nitro-glycerine, it will be remembered, contains slightly more oxygen than is necessary for its complete combustion, but nitro-cellulose, on the other hand, contains a great deal too little. It so happens, however, that the proportions in which these two generally occur in Blasting Gelatine are complementary, and the result is a complete combustion into carbonic acid, water and nitrogen, three very innocuous gases.

The proportions in which they are formed by weight are roughly as follows:—

Carbonic Acid ... ..	61.7%
Water ... ..	20.3%
Nitrogen ... ..	18.0%

The volume produced from one kilo calculated at the average temperature and depth of mine working, viz., 25°C. and 200 metre are as follows:—

192 Litres Nitrogen ... ..	27.48% vol.
422 Litres Carbonic Acid ... ..	72.52% vol.

This is on the assumption, of course, that all the water is condensed.

As already remarked, the other gelatinous explosives used on the South African Fields are on the main only modifications of Blasting Gelatine, but of a lower grade. The best known is "Gelignite," which generally consists of 60% of Blasting Gelatine, and 40% of a mixture of nitrates with some organic matter such as wood pulp. The result is a gelatinous explosive of much the same density as Blasting Gelatine, but about 20% weaker.

I have perhaps now said enough about the explosives used on these fields, but I cannot leave the subject altogether without referring to what is perhaps the most interesting and instructive part which nitro-glycerine plays in the world's economy.

Forty years ago, the idea of being able to tame nitro-glycerine to such an extent that it could be capable of being used as an instrument for industrial development was believed in by few, if any. We have seen, and we know now how all this came about, but even 15 years ago, no one would have believed it possible to further tame it that it could be used as a propellant. Yet this has taken place, and we have in Cordite, perhaps the most powerful propellant ever known, and at the same time the one most easily tamed and most amenable to the requirements of the artillerist. Nitro-glycerine is, of course, the principal ingredient of Cordite, and we have the strange anomaly of its (N.G.) being at one and the same time the most powerful blasting and propelling agent as also the mildest and best mannered of explosives.

To Nobel we are again indebted for this idea, and though his original specification has not been followed in every case, most of the great European Powers have adopted a propellant containing greater or less proportions of nitro-glycerine. The phenomenon of a powder being, at the same time a blasting and a propelling agent is not, of course, unknown, and for hundreds of years our old friend black powder had to act in this capacity, and it is really



statement to make, but consider for one moment what has been done through their agency. Railways have been made through places formerly thought impassable and impossible; tunnels have been bored; harbours made safe for the entry of ships; docks have been blasted; and we all know what tremendous influences are exerted by the railway and by the steamboat. People who ought to know say that the wealth of France and its recuperative powers are almost entirely due to the splendid system of roads inaugurated by Napoleon, but no system of roads could ever do for France, or for any other country, what the railways are doing now all over the world. Could South Africa be what it is to-day without railways, and can it progress industrially or commercially without them? Speaking of South African Railways in particular, however, reminds me that from the point of view of the explosive manufacturer their development does not appear to have involved the use of very much explosive, because, wherever there is a difficulty in the way, the engineer, instead of calling in the mighty aid of explosives, has gone several miles round the corner to avoid it. This by the way.

Of course, nitro-glycerine explosives are employed for mining purposes more than for anything else, and in South Africa we can safely say that no other kind has ever been used to any extent. The Rand could never have been what it is now without nitro-glycerine. During the twelve months prior to the war, 12-15 million tons of gold-bearing rock were mined simply to put through the batteries, but it is impossible to estimate how many more millions were blasted in such work as shaft-sinking, development and prospecting. Gold has been the making of South Africa, and it will yet make it one of the wealthiest and most wonderful countries of the world. Who is there among us here who can foretell what this country will be 20 years hence? It is the few who are pessimists. Why, we have millions upon millions of tons of coal, iron and limestone lying side by side, and if it were not for that bugbear, labour, we who are optimists could look forward to the day when the High Veld would rival Pittsburg, Swansea, Durham and Cardiff—when we have the railways. We live in a white man's country, and must dream white man's dreams. There is nothing impossible, and long after the present Rand is worked out, there will be plenty of scope for the ambitious in other directions. What benefits the Rand, benefits the whole of South Africa. I look forward to the day when industries of all kinds will spring up. They cannot help doing so, but the backbone of the whole must always be gold. I am not speaking of it in the sordid but in the industrial sense, and I say now, with all seriousness, that the progress of South Africa will go hand in hand with the increased use of the subject-matter of this paper.

## 7.—A PRELIMINARY NOTE ON SOME OBSERVATIONS ON ATMOSPHERIC ELECTRICITY IN CAPE TOWN AND BLOEMFONTEIN.

BY DR. J. C. BEATTIE, F.R.S.E., W. H. LOGEMAN, B.A., AND  
J. LYLE, M.A.

Till recently, work on atmospheric electricity embraced observations on thunderstorms and allied phenomena and measurements of the potential at a point in the air. In 1899, Elster and Geitel, following up the work of Linss, proved the presence of gaseous ions in ordinary atmospheric air. This discovery added new interest to the subject, and when one of us came to reside in Bloemfontein, Dr. Beattie suggested that the study of atmospheric electricity might, with great advantage, be carried on simultaneously in Cape Town and Bloemfontein.

The stations are equipped with a Kelvin portable electrometer and an Elster and Geitel "Zerstreuungs Apparatus." The former requires no description; the latter is simply a very sensitive aluminium leaf electroscope, having, in place of the usual disc, a cylinder of blackened brass, radius 2.5 cms., length 10 cms., which is insulated inside of a larger earthed cylinder, radius 9 cms., length 14 cms. The insulation is of such an excellent character that no allowance need be made for loss of charge due to bad insulation. The method of using the instrument is as follows:—The distributor, as the inner cylinder is called, is charged to a potential which can be known from the divergence of the leaves. It is usually 150 to 200 volts. The instrument is then exposed freely in the open air, but out of the direct rays of the sun. A reading is taken in about fifteen minutes, and the instrument, charged oppositely now, is set to leak again.

From the voltage difference it is easy to calculate a number which is proportional to the quantity of electricity which leaked in one minute from the inner cylinder to the outer. This number, hereafter referred to as " $\alpha$ ", may be taken as a measure of the conductivity of the air.

Readings have been taken morning and afternoon, and in Bloemfontein several all-day readings have been obtained.

In Cape Town the instruments are in the charge of Mr. Logeman. The Elster and Geitel is exposed under the balcony in the south front of the Physics Laboratory.

The potential readings are made at a point seven feet above the ground, in the centre of the College Quadrangle.

In Table I. will be found the mean monthly values of " $\alpha$ " for this station.

Mr. Logeman has not been able to find any connection between the conductivity of the air and any of the usual meteorological elements, or even the potential. They are, therefore, not included in the table.

The few potential readings obtained are quite normal in character. They are almost invariably positive, but are subject to great fluctuations. Extremes occurred on 11th September, 1902, when 520 volts positive were registered, and on 9th February, 1903, when a negative reading of 245 volts was obtained.

On neither occasion did anything remarkable occur.

In Bloemfontein the instruments are at Grey College, in charge of Mr. Lyle.

The Elster and Geitel is freely exposed in the open air, with no roof over it as in Cape Town. It is shielded from the direct rays of the sun.

The portable electrometer is set up in the middle of an open space, and at a height of four feet from the ground. Unfortunately, this instrument suffered in transit from England, and it is only recently that potential readings have been taken. Table II. contains the mean monthly values of "*a*" for the Bloemfontein station, as well as the usual meteorological elements in so far as our equipment permitted their observation.

A discussion of the readings at the present stage would be somewhat out of place, but we may draw attention to the following points:—

In the morning the mean negative leak exceeds the positive in almost every case; in the afternoon the mean positive somewhat exceeds the mean negative, but in both stations the afternoon leak is erratic, due probably to the presence of products of combustion in the air.

The afternoon leak is pretty generally greater than the forenoon leak.

Making allowance for various experimental errors, we may state that at any instant the number of positive ions in the air is the same as the number of negative ions, but that the number varies greatly from time to time. Tables I. and II. would seem to point to an annual variation in the number of the ions. The leak is greatest in the summer months. This may point to an insulation effect, which would also explain why the leak is greater in Bloemfontein than in Cape Town, and greater in the afternoon than in the forenoon.

It has been noticed in Bloemfontein that if the leak shows signs of one-sidedness, a break in the weather may be expected.

The negative ions are usually first affected. It is known that they most readily form nuclei for the condensation of aqueous vapour, and, their mass being thereby increased, they move more slowly in an electric field, and so the positive leak is lessened. In dust-storms the leak is somewhat variable, but this may well be due to the convective action of charged dust particles.

There is a decided daily variation. The maximum is reached in the afternoon, just when the temperature is highest and the rela-

tive humidity is lowest. This will be borne out by a reference to Table III., which shows hourly values of " $a$ " for 10th February, 1903. By far the most interesting daily variation occurs just before sunset.

The relative humidity has been known to double itself in a little over an hour, and in the same time the leak has fallen off from quite a high value down to zero. The negative ions are most sensitive. After sunset the air rapidly regains its conductivity, and values of " $a$ " have been got greatly in excess of the usual values. This effect may take place quite apart from any approach to saturation.

Contrary to expectations, great disturbances, such as violent hail, rain and thunderstorms, which are fairly frequent in Bloemfontein, have not, so far, been found to have any great effect on the conductivity of the air. The few potential readings taken in Bloemfontein are of quite the normal kind, positive and steady in fair weather, high "wobbly" readings, usually negative, before and during broken weather.

In dust-storms, the potentials are negative, and so high that the instrument is unable to measure them. If a storm strikes Bloemfontein, the potential is negative and the barometer rises; if the storm passes on one side, the potential is positive and the barometer falls. It seems also that a low potential accompanies good conductivity and a high potential poor conductivity.

Mr. Logeman has designed and is making an instrument to obtain a continuous record of the conductivity of the air, and with it we hope to push our inquiries further, and so verify or amend several conjectural relations between " $a$ " and the other meteorological phenomena.

TABLE I.—MEAN MONTHLY VALUES OF " $a$ " FOR CAPE TOWN.

DATE.	MORNING.		AFTERNOON.	
	+ $a$	- $a$	+ $a$	- $a$
1902.				
June ... ..	·0067	·0070	·0116	·0107
July ... ..	·0086	·0091	·0154	·0155
August ... ..	·0061	·0073	·0119	·0119
September ... ..	·0086	·0078	·0120	·0106
October ... ..	·0093	·0096	·0104	·0097
November ... ..	·0122	·0134	·0126	·0144
December ... ..	·0108	·0116	·0064	·0071
1903.				
January ... ..	...	...	...	...
February ... ..	·0080	·0084	...	...

TABLE II.—MEAN MONTHLY VALUES OF "a" FOR BLOEMFONTEIN.

DATE.	MORNING.					AFTERNOON.				
	Temp.	Rel. Hum.	Bar.	+ a	— a	Temp.	Rel. Hum.	Bar.	+ a	— a
1902—										
Sept. ...	57	61	—	'0114	'0116	67	43	—	'0133	'0153
Oct. ...	63	53	—	'0126	'0137	70	39	—	'0133	'0127
Nov. ...	64	74	—	'0152	'0168	71	54	—	'0144	'0137
Dec. ...	77	63	—	'0138	'0151	88	46	—	'0171	'0182
1903—										
Jan. ...	71	52	25·551	'0152	'0162	86	28	—	'0207	'0204
Feb. ...	69	62	25·681	'0151	'0164	77	48	—	'0184	'0167

TABLE III.—MEAN HOURLY VALUES OF "a" AT BLOEMFONTEIN ON 10TH FEBRUARY, 1903.

Hour.	Value.	Hour.	Value.
7-8	'0110	2-3	'0240
8-9	—	3-4	'0228
9-10	'0145	4-5	'0180
10-11	'016	5-6	—
11-12	'0225	6-7	'0070
12-1	'0270	9-10	'0330
1-2	'0135	—	—

## 8.—A GEODESIC ON A SPHEROID AND AN ASSOCIATED ELLIPSE.

BY LAWRENCE CRAWFORD, M.A., D.Sc., F.R.S.E.

1. In this paper the length of the arc of a geodesic drawn from a given point on a spheroid in a given direction is found as the length of an arc of an ellipse, and the difference of the longitude of any point on the geodesic and the given point is expressed as an elliptic function of an angle connected with the corresponding points on the same ellipse. An expression is then found for the change in longitude on return along the geodesic to the same latitude.

2. The equation of the spheroid is  $\frac{x^2+y^2}{a^2} + \frac{z^2}{c^2} = 1$ ,

and a geodesic is given by  $r^2 \sin^2 \theta \frac{d\phi}{ds} = \text{constant}$ , where  $\theta$  is latitude, measured from  $OZ$  and  $\phi$  is longitude.

Also  $ds^2 = d\sigma^2 + r^2 \sin^2 \theta d\phi^2$ , where  $d\sigma$  is element of arc of meridian ellipse, and the co-ordinates of the point in the plane of the meridian may be written  $(a \cos u, c \sin u)$  where  $a \cos u = r \sin \theta$ ,  $c \sin u = r \cos \theta$ .

By substitution for  $d\sigma^2$  in terms of  $du^2$ , and for  $\theta$  in terms of  $u$ , we find equation of geodesic becomes

$$a^2 \cos^2 u \left( \frac{a^2}{m^2} \cos^2 u - 1 \right) d\phi^2 = a^2 (1 - c^2 \cos^2 u) du^2$$

where  $m$  is the constant of the geodesic and  $c^2 = 1 - \frac{c^2}{a^2}$ .

Also by the same substitutions we find

$$ds^2 = \frac{a^4}{m^2} \cos^2 u (1 - c^2 \cos^2 u) du^2 \left/ \left( \frac{a^2}{m^2} \cos^2 u - 1 \right) \right.$$

3. If  $\psi$  be the angle at which the geodesic crosses the meridian,  $r \sin \theta d\phi = ds \sin \psi$ ,

and  $r^2 \sin^2 \theta \frac{d\phi}{ds} = m$  becomes  $r \sin \theta \sin \psi = m$ ,

$$\text{i.e., } a \cos u \sin \psi = m,$$

$$\text{or } a \cos u_0 \sin \alpha = m,$$

where  $u_0$  is eccentric angle of starting point and  $\alpha$  the angle geodesic makes with meridian at  $u_0$ .

Hence we get  $ds^2 = \frac{a^2 \cos^2 u (1 - c^2 \cos^2 u)}{\cos^2 u - \cos^2 u_0 \sin^2 \alpha} du^2$ .

Write in this  $\sin u = \sin \nu \sqrt{1 - \cos^2 u_0 \sin^2 \alpha} = p \sin \nu$ ,  
 then  $\cos^2 u - \cos^2 u_0 \sin^2 \alpha = 1 - \sin^2 u - (1 - p^2)$   
 $= p^2 \cos^2 \nu$

$$\therefore ds^2 = a^2 d\nu^2 (1 - c^2 + c^2 p^2 \sin^2 \nu)$$

$$\therefore s = \int a \sqrt{1 - c^2 + c^2 p^2 \sin^2 \nu} d\nu$$

$$\therefore s = a \sqrt{1 - c^2 + c^2 p^2} \int \sqrt{1 - \frac{c^2 p^2}{1 - c^2 + c^2 p^2} \cos^2 \nu} d\nu.$$

Draw then an ellipse, semi-major axis  $a \sqrt{1 - c^2 + c^2 p^2}$ , that is  $a \sqrt{1 - c^2 \cos^2 u_0 \sin^2 \alpha}$ , eccentricity  $\frac{cp}{\sqrt{1 - c^2 + c^2 p^2}}$ , that is

$$e \sqrt{\frac{1 - \cos^2 u_0 \sin^2 \alpha}{1 - c^2 \cos^2 u_0 \sin^2 \alpha}}$$

then arc of geodesic from point, eccentric angle  $u_0$  to point, eccentric angle  $u$ , where  $\tan(\text{colatitude}) = \frac{a}{c} \cot(\text{eccentric angle})$ , is arc of this ellipse from point, eccentric angle  $\nu_0$  to point, eccentric angle  $\nu$ ,

$$\text{where } \sin u = \sin \nu \sqrt{1 - \cos^2 u_0 \sin^2 \alpha}.$$

Note the semi-minor axis of this ellipse

$$= a \sqrt{1 - c^2 \cos^2 u_0 \sin^2 \alpha} \times \sqrt{1 - \frac{c^2 (1 - \cos^2 u_0 \sin^2 \alpha)}{1 - c^2 \cos^2 u_0 \sin^2 \alpha}}$$

$$= a \sqrt{1 - c^2}$$

=  $c$ , semi-minor axis of spheroid.

4. The relation between  $\phi$  and  $u$  is

$$d\phi^2 \cos^2 u \left( \frac{a^2}{m^2} \cos^2 u - 1 \right) = (1 - c^2 \cos^2 u) du^2.$$

Take the above ellipse and let  $x$  be the angle made with the major axis by the perpendicular on the tangent at the point whose eccentric angle is  $\nu$ ,

$$\text{then } \tan \nu = \frac{c}{a_1} \tan x, \text{ where } a_1 \text{ is semi-major axis of ellipse.}$$

Turn the relation between  $\phi$  and  $u$  into one between  $\phi$  and  $x$ , and, after some reduction, we find

$$d\phi^2 = \frac{a^2 (1 - p^2) (1 - c^2) dx^2}{a_1^2 (1 - k^2 \sin^2 x) (1 - \frac{k^2}{c^2} \sin^2 x)^2},$$

where  $k$  is eccentricity of ellipse, i.e.,  $c \sqrt{\frac{1 - \cos^2 u_0 \sin^2 \alpha}{1 - c^2 \cos^2 u_0 \sin^2 \alpha}}$ , and

modulus of elliptic functions connected with the length of an arc of the ellipse and the length hence of an arc of the geodesic.

$$\therefore d\phi = \frac{\cos u_0 \sin \alpha (1-c^2)}{\sqrt{1-c^2 \cos^2 u_0 \sin^2 \alpha}} \cdot \frac{dx}{(1-\frac{k^2}{c^2} \sin^2 x) \sqrt{1-k^2 \sin^2 x}}$$

To put this into Jacobi's form for the 3rd Elliptic Integral, in which the factor in the denominator is  $1 - k^2 \operatorname{sn}^2 A \operatorname{sn}^2 w$ , take

$\operatorname{sn} A = \frac{1}{c}$  which lies between 1 and  $\frac{1}{k}$ , that is take  $A = K + i\beta$ .

Also take  $\int_0^x \frac{dx}{\sqrt{1-k^2 \sin^2 x}} = w$ , i.e.,  $x = \operatorname{am}(w, k)$ , and remembering

$$\int_0^w \frac{dx}{(1+n \sin^2 x) \sqrt{1-k^2 \sin^2 x}} = w + \frac{\operatorname{sn} A}{\operatorname{cn} A \operatorname{dn} A} \Pi(w, A)$$

where  $n = -k^2 \operatorname{sn}^2 A$ , we get

$$\phi - \phi_0 = \frac{\cos u_0 \sin \alpha (1-c^2)}{\sqrt{1-c^2 \cos^2 u_0 \sin^2 \alpha}} \times$$

$$\left[ w - w_0 + \frac{\operatorname{sn}(K+i\beta)}{\operatorname{cn}(K+i\beta) \operatorname{dn}(K+i\beta)} \{ \Pi(w, K+i\beta) - \Pi(w_0, K+i\beta) \} \right]$$

$$\text{but } \operatorname{sn}(K+i\beta) = \frac{1}{c} \quad \therefore \operatorname{cn}(K+i\beta) = \frac{-i\sqrt{1-c^2}}{c}, \operatorname{dn}(K+i\beta) = \frac{\sqrt{c^2-k^2}}{c};$$

substituting these and putting in the value of  $k$ , we get

$$\phi - \phi_0 = \frac{\cos u_0 \sin \alpha (1-c^2)}{\sqrt{1-c^2 \cos^2 u_0 \sin^2 \alpha}} (w - w_0) + i \{ \Pi(w, K+i\beta) - \Pi(w_0, K+i\beta) \}.$$

5. From the relation between  $\phi$  and  $u$  we must have

$$\frac{a^2}{m^2} \cos^2 u - 1 \text{ positive}$$

$$\text{i.e., } a^2 \cos^2 u - a^2 \cos^2 u_0 \sin^2 \alpha \text{ positive}$$

$$\therefore p^2 - \sin^2 u \text{ positive}$$

and greatest values of  $u$  are  $+\sin^{-1}p$ , but  $\sin u = p \sin v$

$\therefore$  greatest values of  $v$  are  $+\frac{\pi}{2}$ ,

$\therefore$  as we go round geodesic, the corresponding point on ellipse moves completely round it.

The whole length of ellipse then is equal to the length of the geodesic from a value of  $u$  back to the same value.

What is the difference between the original value of  $\phi$  and its value on return to the same value of  $u$ ?

As  $\nu$  goes through the series of values from 0 to  $2\pi$ , so does  $x$ , or we take  $x$  goes from  $x_0$  to  $2\pi + x_0$ , and in this increase in  $w =$

$$\int_{x_0}^{2\pi + x_0} \frac{d\psi}{\sqrt{1 - k^2 \sin^2 \psi}} = \int_0^{2\pi} \frac{d\psi}{\sqrt{1 - k^2 \sin^2 \psi}} = 4K$$

and  $\Pi(w, K + i\beta)$  taken between the limits

$$\begin{aligned} &= \Pi(w + 4K, K + i\beta) - \Pi(w, K + i\beta) \\ &= \int_{4K}^{w+4K} + \int_0^{4K} - \int_0^w \left\{ \frac{k^2 \operatorname{sn}(K + i\beta) \operatorname{cn}(K + i\beta) \operatorname{dn}(K + i\beta) \operatorname{sn}^2 \lambda d\lambda}{1 - k^2 \operatorname{sn}^2(K + i\beta) \operatorname{sn}^2 \lambda} \right\} \\ &= \int_0^{4K} \frac{k^2 \operatorname{sn}(K + i\beta) \operatorname{cn}(K + i\beta) \operatorname{dn}(K + i\beta) \operatorname{sn}^2 \lambda d\lambda}{1 - k^2 \operatorname{sn}^2(K + i\beta) \operatorname{sn}^2 \lambda} \\ &= 4\Pi(K, K + i\beta); \end{aligned}$$

$$\therefore \text{total change in } \phi = \frac{4 \cos u_0 \sin \alpha (1 - c^2)}{\sqrt{1 - c^2 \cos^2 u_0 \sin^2 \alpha}} K + 4\Pi(K, K + i\beta).$$

$$\Pi(u, A) - uE(A) = \Pi(A, u) - AE(u),$$

$$\text{and } \Pi(K + i\beta, K) = 0$$

$$\therefore \Pi(K, K + i\beta) = KE(K + i\beta) - (K + i\beta)E.$$

Apply the addition theorem for  $E(u + v)$  to  $E(K + i\beta)$ , and turn  $E(i\beta)$  into terms of  $E(\beta, k')$ ,

$$\text{and we find } \Pi(K, K + i\beta) = i\beta(K - E) + \frac{iK \sqrt{(1 - c^2)(c^2 - k^2)}}{c} - iKE(\beta, k').$$

$\therefore$  total change in  $\phi$

$$= \frac{4 \cos u_0 \sin \alpha (1 - c^2)}{\sqrt{1 - c^2 \cos^2 u_0 \sin^2 \alpha}} K + 4 \left[ i\beta(K - E) + \frac{iK \sqrt{(1 - c^2)(c^2 - k^2)}}{c} - iKE(\beta, k') \right]$$

$$\text{and } \frac{\cos u_0 \sin \alpha}{\sqrt{1 - c^2 \cos^2 u_0 \sin^2 \alpha}} = \frac{\sqrt{c^2 - k^2}}{c \sqrt{1 - c^2}}$$

$\therefore$  total change in  $\phi$

$$\begin{aligned} &= \left\{ \frac{4 \sqrt{c^2 - k^2}}{c \sqrt{1 - c^2}} K - \frac{4\beta}{1 - c^2} (K - E) - \frac{4 \sqrt{c^2 - k^2}}{c \sqrt{1 - c^2}} K + \frac{4K}{1 - c^2} E(\beta, k') \right\} (1 - c^2) \\ &= 4 \{ KE(\beta, k') - \beta(K - E) \} \end{aligned}$$

where  $\beta$  is given by  $\operatorname{sn}(K + i\beta) = \frac{1}{c}$  or  $\operatorname{dn}(\beta, k') = c$ .

## 9.—A CONSIDERATION OF CLOSE BINARY SYSTEMS IN RELATION TO LIGHT VARIATION.

BY ALEX. W. ROBERTS, D.Sc., F.R.A.S., F.R.S.E.

If two stars revolve round one another in such a manner that at every revolution each component comes between its companion star and the earth, it is evident that the total light which comes from the system will undergo periodic and regular variation.

This phenomenon of stellar variation, of a well-defined type, is exceedingly interesting, not only because it affords a striking manifestation of celestial movement, but also because it yields data which may be of service in investigating some of the most important problems of modern Astronomy, for it will be plain that the character of the periodic eclipse due to orbital movement will be determined to a considerable extent by the relative size and brightness of the two stars forming the system; or, to put the matter the other way, light variation of a certain well-defined character will be no untrustworthy indication of the dimension and brightness of the stars producing the variation. From the form and dimensions of any stellar orbit to the weight and density of the stars circling in this given orbit is but a step.

Thus the obscuration of the light of any star by a revolving companion is an occurrence of far more significance than at first sight appears. It is this intimate relation of stellar variation to celestial mechanics that has during the past ten years raised the study of variable stars from being a pastime to a science.

It is no doubt unnecessary to point out here that all light variation is not due to eclipse; it is only variation of a certain definite type that is caused by the revolution of one star round another. Further, all binary stars do not exhibit light eclipse. It is only when they move in such an orbit that at every revolution one or other of the two stars comes into the line of sight that eclipse takes place. When, however, any star revolves round another in an orbit whose plane is coincident, or nearly so, with the plane of sight, eclipse will occur; and this eclipse will, as we have said, be of a certain definite type, of a character so marked that there will be no chance of mistaking the light changes for variation of a different type, and due to totally different causes.

A moment's thought will indicate what the prominent features of this type of variation—called Algol variation from the remarkable close binary Algol—are:—

- (1) First, we will have great regularity of light changes. One cycle of variation will be exactly like another cycle.
- (2) The full cycle of light changes will be completed in a few days, sometimes in a few hours.
- (3) The ascending and descending periods of variation will be, approximately, equal in duration.

Although, however, all variable stars of the Algol type, that is, close binary stars revolving in an orbit coincident, or nearly so, with the plane of sight, will conform to a general type of variation, there will be individual differences in the character and magnitude of the light changes of each star, marking it out unmistakably from its fellows. The two stars forming a system may be equal in brightness, or they may be very unequal: they may be equal in size, or the disparity may be very great: they may move round one another in contact, or two or three diameters apart: they may circle exactly in a plane coincident with the plane of sight or at an appreciable inclination to it: their orbit may be circular or elliptical. Thus, while the general type of variation is due to the common fact of revolution, the individual distinctive features of each system are due to the relative size, brightness and movements of the component stars.

Each Algol variable, therefore, will have a separate light curve of its own, possessing certainly the general family features of all Algol stars, but, also, at the same time possessing individual characteristics which mark it out distinctly from all other variable stars of the same class.

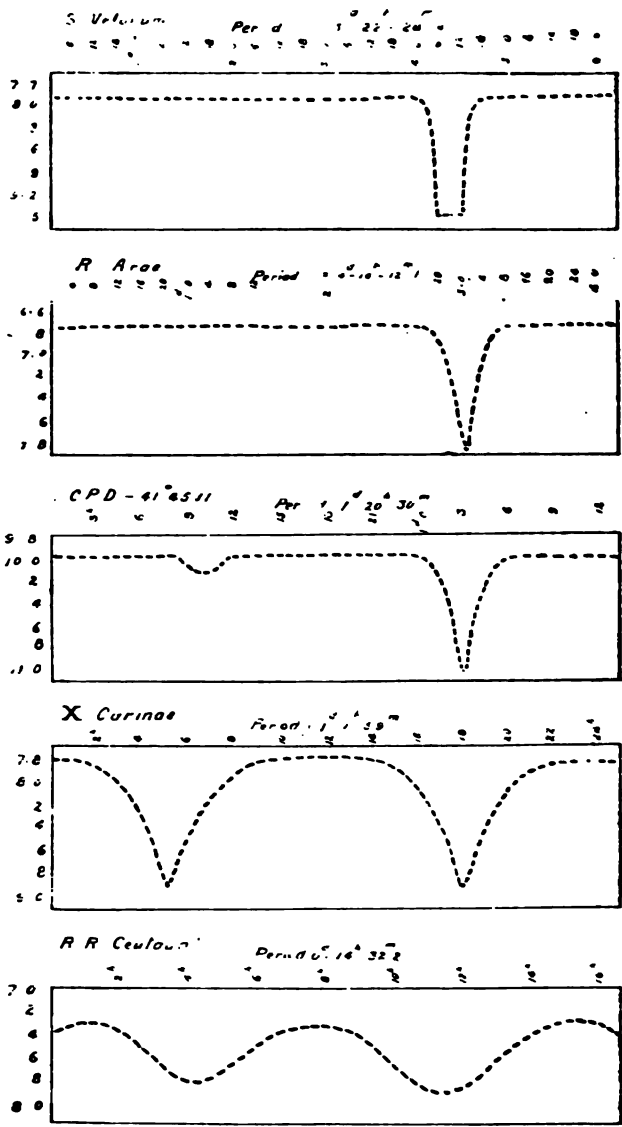
Perhaps this common family likeness, and yet individual distinctive difference, will be best illustrated by exhibiting the light curves of five typical southern Algol variable stars. These five typical stars are:—

No.	STAR.	R.A. 1900.			DEC.
		H.	M.	S.	
1.	S Velorum ... ..	9	29	27	-44°-45'9"
2.	R Arae ... ..	16	31	26	50-47'6
3.	CPD-41°4511 ... ..	10	17	48	41-45'3
4.	X Carinae ... ..	8	29	7	58-53'2
5.	RR Centauri ... ..	14	9	55	-57-23'3

An exhaustive examination of even the minutest details of these five typical light curves, Fig. 1, would prove of no ordinary interest. It is beyond the province, however, of this paper to enter upon such an investigation. I would confine myself rather to a consideration of the outstanding features of each type, and will endeavour to exhibit the principal conditions of matter and motion which lie behind these features.

It will be observed that in the first two light curves that of the binary systems S Velorum and R Arae, there is only one depression. That is, in the case of S Velorum, R Arae, and all stars of this type of variation, there is only one eclipse every revolution. These binary systems are composed of two stars, one bright, the other quite dark. When the dark star gets in front of the bright one we have the observed eclipse: when the bright star gets in front of the dark one there is of course no change in the brightness of the system.

FIG. I.



In the third light curve, that of CPD—41° 4511 there is a double depression, one being very slight. In this case the fainter star is sufficiently bright to manifest a secondary eclipse when the brighter companion gets in front of it. The primary eclipse takes place when the faint component obscures the light of the bright one. It may be mentioned here that in the case of CPD—41° 4511 the brighter star is six times more lustrous than the fainter star, although it is of the same size.

In the fourth and fifth light curves we have represented a remarkable class of binary stars. Both X Carinae and RR Centauri exhibit two almost equal eclipses each revolution. The interpretation of this is that these systems are composed of two stars almost equal in size and brightness.

Thus in the five light curves exhibited in Fig. 1 we have testimony to at least three stages of double star evolution:—

- (1) First, when both stars of a binary system are equal in brightness. This is in all probability the first stage. X Carinae and RR Centauri may be taken as types of this sub-division. As a rule these stars circle round one another in a very short period, usually a few hours.
- (2) Second, when one star is distinctly fainter than the other. For some reason or another one of the components has cooled down: it has reached the second stage in its development.
- (3) Third, when one of the twain is quite dark. This is the third stage. What stages still lie before the chilled mass we cannot tell. It may become a fertile planet or a sterile satellite.

These are the three outstanding facts which we can deduce from the five light curves under consideration. But when we carry our inspection one step further we find important differences between each one of the five curves.

Thus we observe that the eclipse of S Velorum (1st light curve) remains at its minimum phase for six hours. In the case of R Arae (2nd light curve) there is no halting when the light changes have reached their ebb: flow follows ebb without a halt in the variation of this star.

The only sufficient explanation of the constant minimum phase of S Velorum is this, that the dark companion of this binary system is many times larger than its bright companion. This seems such a strange reversion of the natural order of things—a small central sun and a large dark satellite that at first sight one is inclined to set this explanation aside. Yet no other has been offered. And I take it the explanation is a rational one, as I hope to indicate later on.

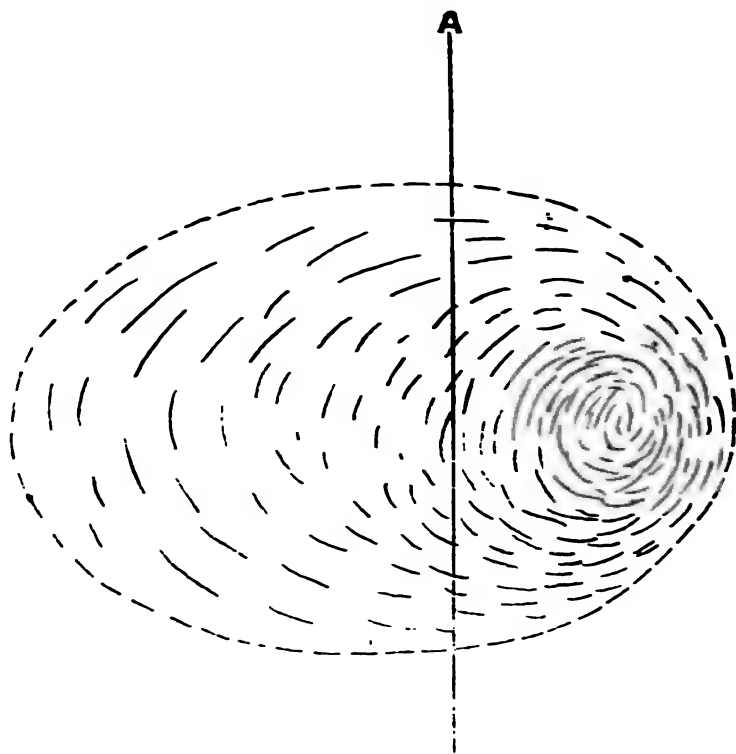
It will be observed also that the light curves of X Carinae or RR Centauri, while alike in essential feature, are different in one or two not unimportant particulars. Thus the light curve of RR Centauri has no constant phase at all, however short. Its light curve

is a succession of waves. That is the two stars which make up this system circle round one another as *normal*.

In the case of X Carinae separation has taken place. The component stars are nearly half the diameter of either of them apart.

It would be entirely out of place to present the system of equations which connect the light changes of any Algol binary system, as exemplified by its light curve, with the orbital movements and magnitudes which produce them.

FIG. 2.



It will be more pertinent to the present line of inquiry to consider one or two of the problems which have arisen out of the foregoing statement of our present knowledge of close binary systems. These problems I take it are of considerable interest and importance. Some of them have already been indicated.

(A.) It may be demonstrated, as already stated, that the variation of such stars as S Velorum—there is another exactly similar,

RR Puppis, in the Southern Hemisphere, and both stars were discovered at the Royal Observatory, Cape Town—is due to the rotation of a large dark body round a small bright companion.

We have said that at first sight this seems a strange and contradictory state of things; yet I venture to offer a rational and simple explanation.

Let us consider a mass of tenuous matter rotating on its axis. It is not unreasonable to suppose that the nucleus of such a system might be nearer one side than the other: and that in eccentric layers the whole mass condensed round this nucleus. That is, we would have a body such as is imperfectly represented in Fig. 2.

It is evident that such an unstable condition of mechanical adjustment would favour bipartition: whereas a sphere-shaped body, perfectly symmetrical and uniform in structure, would present no line along which cleavage might take place.

Now, constriction setting in along the line AB (Fig. 2), and this leading, after the lapse of countless ages, to bipartition, there would result two bodies, one dark, large, light: the other bright, small, dense.

We would have the very condition of things which exists in stars of the type of S Velorum. In process of time the larger body might still further divide and sub-divide—the irregular density of the mass would favour such disruption.

Is it possible that in a star like S Velorum we have the first beginnings of another solar system?

(B.) The question of the density of close Binary stars is intimately connected with the preceding inquiry, and, therefore, with all problems dealing with the evolution of stellar systems. Indeed, the density of an Algol Binary is a question of fundamental importance in Astrophysics.

It is fortunate that this inquiry admits of rigorous treatment. The equations of orbital movements and dimensions can be related directly to the density of occulting binary stars. The investigation premises great refinement of observations, as all cosmical problems do, but granted this accuracy of data, the deductions are incontrovertible.

It is found that the density of all close binary systems is, without exception, many times lighter than that of the sun. For example, it is found that the mean density of eight southern Algol stars comes out as one-eighth that of the sun.

This is a remarkable result; and none the less remarkable from the fact that it is the state of things we would expect to find in a binary system that just have been evolved from some irregular gaseous mass. The result proves that at their genesis close binary stars are composed of matter "light as air."

(C.) We have stated that the light curve of RR Centauri, and of four other Algol stars, indicate that the light changes of this class of binary stars are caused by the revolution of two bodies in contact.

One of the problems that presented itself to the writer several years ago, when the first star of this type was discovered, was: is it possible to ascertain the *shape* of the stars continually eclipsing one another?

A first investigation proved that to deal with this problem with any hope of even partial success, necessitated observations of great refinement. A new telescope was, therefore constructed with the sole purpose of obtaining measurements as accurate as human skill could secure.

Lately, also, there has been added to this telescopic equipment the photometers used by Professor Prichard at Oxford, England.

But even with the most favourable conditions of seeing and measuring, I question whether we will be able, with our present limitations, to secure observations refined enough to respond to the exacting demands of the problem.

For to deal with the whole problem fully would mean our being able not only to distinguish but to measure the change in the amount of light given out by a candle at 100 feet distant, as compared with the same candle at 101 feet. It is unnecessary to say that the eye can with difficulty distinguish differences so minute as this.

But although the problem does not admit of an absolute solution, it admits of a solution so nearly absolute that it is of importance to indicate what has been accomplished in this direction.

If two stars revolve round one another in contact the stress and strain of their mutual attraction will produce considerable deformation in both stars. They will no longer be spherical in figure, but will be egg-shaped masses with their narrower ends in contact.

For the exact figure of equilibrium which rotating masses of fluid would take under the combined influence of attraction, tidal action and rotation, the curious are referred to Professor Darwin's classical investigations. (Phil. Trans., Vol. 178, Plates 22, 23.)

We have already indicated that it is impossible to secure observation refined enough to enable us to determine rigorously the exact form which a close binary star, say RR Centauri, assumes just when separation has taken or is taking place. The furthest we can go without the risk of making our equations indeterminate is to assume a spheroidal figure for the twin stars. That is, we postulate *two* unequal axes for each star.

Interpreting the light changes of RR Centauri into orbital movement, with this limitation, we find that the system is composed of two stars, spheroidal in figure, with their major axes lying along the line joining their centres. A sectional representation of the system is given in Fig. 3.

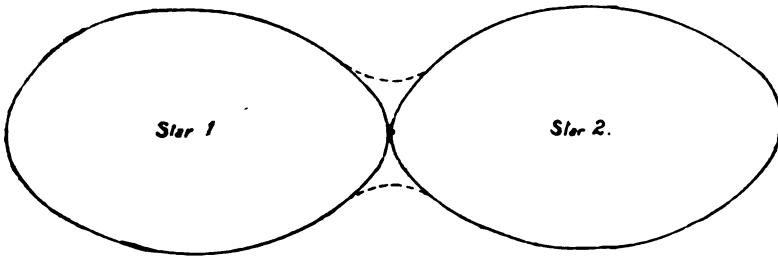
In Fig. 4 are given the figures of equilibrium which two rotating masses of fluid would assume when *nearly* in contact. The figures are copied from Professor Darwin's masterly work.

The similarity between the figures determined from pure observation alone, and the theoretical figures derived from a consideration

of the Laws of Attraction, is sufficient to warrant the belief that if at any future time the limitations now hampering the rigorous treatment of the problem were removed, theory and observation would be in complete harmony.

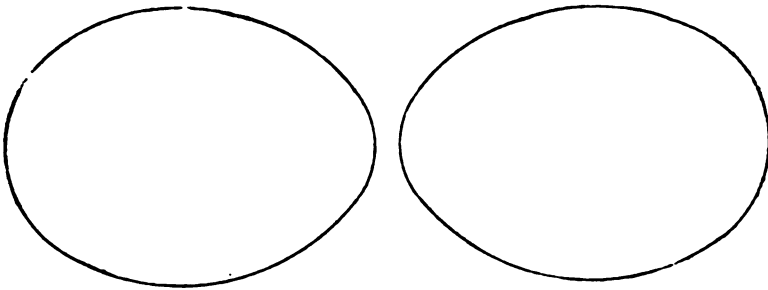
FIGURE OF EQUILIBRIUM OF R. R. CENTAURI *as obtained from observations.*

FIG. 3.



FIGURES OF EQUILIBRIUM OF TWO ROTATING MASSES OF FLUID ALMOST IN CONTACT. (*Darwin ... Phil. Trans., Vol. 178, p. 429.*)

FIG. 4.



*Perpendicular Section.*

How wide binary systems such as "Centauri, Sirius, and Castor are evolved from close binary systems like RR Centauri belongs to the region of confident speculation. We know that tidal action would tend to make all binary systems circle in ever-widening orbits, forming infinite spirals. But as the security of our

belief in such a development is founded on the operations of law rather than on the evidences of our vision, I may not enter further into the question.

As no unimportant part of the New Astronomy will be the study of close binary systems, I trust that what has been written will be of interest to members of the Association.

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10.—THE DETERMINATION OF MEAN RESULTS FROM  
METEOROLOGICAL OBSERVATIONS MADE AT  
SECOND-ORDER STATIONS ON THE TABLE-  
LAND OF SOUTH AFRICA.

By J. R. SUTTON, M.A.CANTAB.

For the purposes of this paper a daily "mean result" is understood to be the average of twenty-four hourly observations. It differs little from the true mean obtained by a planimeter from an automatic continuous record.

The ordinary time of the observations made by voluntary observers for the Meteorological Commission is at present VIII. Cape Colony mean time for the meridian of  $22\frac{1}{2}^{\circ}$  E., but there are occasional registers where other hours have been used. It will be found that it is not possible to compare together the climates of two stations when different hours of observation are used at each, until the departure from the true mean is determined. The station using the later morning hour of the two will, on account of the single observation, indicate a climate hotter and drier than the other. There is a further point, that even where many stations use the same hour (VIII. C.C.M.T., say), the eastern stations shew hotter and drier than the western, because of the difference between civil and apparent time. Thus, *e.g.*, there is a difference of apparent time between Port Nolloth and Umtata of upwards of three-quarters of an hour; and it happens, consequently, that the VIII. observations at the former place are not far from 7.40 a.m., and the latter not far from 8.30 a.m., local time. Since both temperature and humidity are varying most rapidly on the table-land between these times, it follows that the results from each are not comparable until some allowance has been made for the variation. Of course, in discussing the question of mean results, the registrations of maximum and minimum temperatures, which are, in a way, independent of time, get over one aspect of the difficulty of comparison so far as the temperature alone is concerned. The dew-points, humidity-ratios, and barometric-pressures, however, are not so relieved. The object of this communication is to give material for reducing these, as well as the temperatures, to a common standard of reference. It must be understood as dealing with the central table-land of South Africa, including such stations as Aliwal North, Philippolis, Bloemfontein, Hanover; and generally with all such as shew an approach to equality in the ratios  $a_M : a_m$  of the amplitudes of the first harmonic terms in the formulæ for the daily maximum and minimum temperatures. Umtata, Queenstown, Worcester, etc., are rather outside its scope, although it will be applicable to some Eastern Province stations also in a limited degree. Stone, when H.M. Astronomer at the Cape, collected some materials which he

used for the purpose of reducing the coast observations, but with how much success is not known. From observations made during the six years 1841-6 he determined a series of corrections to be applied to observations made at the Royal Observatory at any hour to obtain the true mean. These have been published in some of the earlier Annual Reports of the Meteorological Commission. He further deduced the formula to the second harmonic term:—

$$d = 4^{\circ} 58' \sin (15h + 58^{\circ} 43') + 1^{\circ} 30' \sin (30h + 62^{\circ} 29'),$$

where  $d$  is the deviation from the mean temperature, and  $h$  the number of hours from Cape mean noon. This is of historic interest, as being the only result ever evolved by a Cape Observatory official from the mountainous piles of routine meteorological observations accumulated there.

No suitable material exists for the reduction of cloud, although it is not improbable that the observations at VIII. may give a very fair approximation to the mean. And, finally, it is opportune to mention, though the matter is somewhat outside the limits of this paper, that observations of wind-direction at VIII. may only be used in comparing one month with another; they give otherwise no information of any value. There is a very strong diurnal variation in the surface wind-movement over the table-land, and pretty well every item of infallible weather-wisdom, involving a wind factor, in circulation, is fundamentally unsound through not taking it into account.

In Table 1 will be found the annual values of Pressure, Temperature, Dew-point, and Humidity, derived from observations made hourly during the five years 1898-1902. The dew-points and humidity-ratios are determined by means of the Greenwich factors, and are therefore liable, particularly in the dry hours about mid-day, to whatever inaccuracy Glaisher may be supposed to have introduced. They are also in error to a certain extent, because they are derived from the indications of a wet bulb in ordinary air, which is known to read higher on the whole than when it is placed in a forced draught. It is important to observe that the dew-points and humidity-ratios are computed for each observation, and not, as is sometimes done, by applying the factors to the monthly means of dry and wet bulbs: the latter process makes the dew-point a little, and the humidity-ratios a great deal too small. The hours of observation are reckoned in the old hours of Cape Colony civil time ( $22\frac{1}{2}^{\circ}\text{E.}$ ), from midnight to XXIII. Kimberley being some  $2^{\circ} 10'$  to the east of this, each consecutive mean value properly belongs to the local times oh. gm., 1h. gm., 2h. gm. . . . . This is important in applying the results to stations in different longitudes.

When we compare the mean values at VIII. with the means for the day, we see at once how wide of the mark our appreciation of the climate is likely to be if we take only the results of second-order stations to define it. The pressure is  $0\cdot4$  inch, or nearly one-half its whole daily range in excess; the temperature is  $4^{\circ}$  too low; the dew-point is nearly a degree, and the humidity nearly seven per cent. too high. Also the mean of the registered maximum and

minimum shade temperatures—usually represented by  $\frac{1}{2} (M+m)$ —is rather more than a degree above the mean. Readings at XX. would give much closer approximations to the true means. In fact really excellent normals might be obtained thus by dropping the third decimal place in the pressure, taking the temperature equal to  $\frac{1}{3} (M+m+t_{11})$ , the dew-point and humidity not requiring alteration.

For single daily observations at a fixed hour, to give the annual means, we have the following:—

Pressure	... ..	II., or XXI.
Temperature	... ..	8.45 a.m., or 7.30 p.m.
Dew-point	... ..	VII., XVI., or XX.
Humidity	... ..	8.45 a.m., or XX.

If we resolve the annual normal curve of pressure into its harmonic constituents, we may represent it by the following formula:—

$$\begin{aligned}
 P = p + & \cdot 0276 \sin (n15^{\circ} + 357^{\circ} 5) \\
 & + \cdot 0245 \sin (n30^{\circ} + 158^{\circ} 7) \\
 & + \cdot 0017 \sin (n45^{\circ} + 357^{\circ} 1) \\
 & + \cdot 0002 \sin (n60^{\circ} + 330^{\circ} 0) \\
 & + \dots\dots\dots
 \end{aligned}$$

Here the term of second order vanishes for the epochs oh. 43., a.m. and p.m. Also for any pair of homonymous hours the sum of the terms of first and third (in fact any odd) constituent will annul each other, so that the mean of the observations at either pair of hours will be equal to the mean of the day, plus the value of the fourth constituent. This last, being  $\cdot 0002$  inch at most, at any hour, and, in fact, only  $\cdot 00004$  inch for the times in question, may be neglected. So that for two observations per diem, these will give a true annual mean. The night hour, however, would not be convenient enough to allow the pair to which it belongs to come into general use.

Again, the term of third order vanishes at oh. 4m., 4h. 4m., 8h. 4m., a.m. and p.m. Also for any triplet of hours eight hours apart, it is easy to prove that the sum of the terms of the first, second and fourth order annul each other; and, therefore, the mean of the three observations at either (oh. 4m., 8h. 4m., 16h. 4m.) or (4h. 4m., 12h. 4m., 20h. 4m.) will be equal to the mean of the day. It will be sufficient to outline the proof for the first—and most important—constituent; those for the others being constructed upon similar, though simpler, lines:—

Let  $t$  be any hour: Then

$$\begin{aligned}
 \sin [V_1 + (t+16) 15^{\circ}] + \sin [V_1 + (t+8) 15^{\circ}] \\
 = 2 \sin [V_1 + (t+12) 15^{\circ}] \cos 60^{\circ} \\
 = \sin [V_1 + (t+12) 15^{\circ}] \\
 = - \sin (V + t 15^{\circ})
 \end{aligned}$$

Again, the fourth component vanishes eight times a day, at oh. 30m., 3h. 30m., 6h. 30m., 9h. 30m., a.m. and p.m. Also for any four hours, six hours apart, the sum of the terms of first,

second and third order annul each other, and therefore the mean of the four observations from either set, six hours apart, will be equal to the mean of the day. Since, however, the fourth component is practically zero at any hour, the mean of any four observations equi-distant at six hour intervals will give the true mean.

The annual normal curve of temperature is represented by the formula :—

$$T = t + 1.2247 \sin (n15^{\circ} + 231^{\circ}0) \\ + 3.068 \sin (n30^{\circ} + 61^{\circ}8) \\ + .741 \sin (n45^{\circ} + 23^{\circ}9) \\ + .803 \sin (n60^{\circ} + 226^{\circ}2) \\ + \dots\dots\dots$$

Following the same line of reasoning here as we did for the pressure, we see that the second component vanishes at 3h. 56m., and 9h. 56m., a.m. and p.m. Hence, since for either homonymous pair the value of the fourth constituent is approximately  $0^{\circ}8$ , it follows that the mean of the temperatures of either pair will exceed the true annual mean by about three-quarters of a degree.

The term of third order vanishes for the epoch 3h. 28m., 7h. 28m., 11h. 28m., a.m. and p.m.; and, therefore, we may consider the mean of the observations at (3h. 30m., 11h. 30m., 19h. 30m.), or (7h. 30m., 15h. 30m., 23h. 30m.), as giving the mean temperature of the year.

The fourth component vanishes at 2h. 4m., 5h. 4m., 8h. 4m., 11h. 4m., a.m. and p.m.; and, therefore, the observations at (II., VIII., XIV., XX.), or (V., XI., XVII., XXIII.), may be considered the equivalent of the true normal mean.

The annual normal curve of dew-point is given by the formula :

$$D = d + 1.223 \sin (n15^{\circ} + 251^{\circ}2) \\ + .554 \sin (n30^{\circ} + 158^{\circ}9) \\ + .439 \sin (n45^{\circ} + 6^{\circ}2) \\ + .068 \sin (n60^{\circ} + 342^{\circ}1) \\ + \dots\dots\dots$$

In the same way as before, the second component of dew-point vanishes for the epoch 0h. 42m., 6h. 42m., a.m. and p.m. And at these times the fourth constituent is barely  $0^{\circ}03$  in magnitude. The mean of either pair of homonymous times will, therefore, give a fairly true annual mean.

The term of third order vanishes for the epoch 3h. 52m., 7h. 52m., 11h. 52m., a.m. and p.m.; and, therefore, we may regard the observations at (IV., Noon, XX.) or (VIII., XVI., Midnight) as furnishing the equivalent of the normal mean.

The term of fourth order vanishes at 0h. 18m., 3h. 18m., 6h. 18m., 9h. 18m., a.m. and p.m. With sufficient exactness, then, the mean of the observations at (Midnight, VI., Noon, XVIII.), or (III., IX., XV., XXI.), may be called the true mean.

The annual normal curve of relative humidity is given by the formula:

$$\begin{aligned} H = h &+ 18.128 \sin (n15^{\circ} + 47^{\circ}.5) \\ &+ 4.870 \sin (n30^{\circ} + 249^{\circ}.9) \\ &+ 1.180 \sin (n45^{\circ} + 197^{\circ}.2) \\ &+ 1.569 \sin (n60^{\circ} + 44^{\circ}.1) \\ &+ \dots \dots \dots \end{aligned}$$

In the same way as before, the second component vanishes for the epoch 3h. 40m., 9h. 40m., a.m. and p.m. And at these times the value of the fourth component is  $-1.5\%$  very nearly. The mean humidity for either pair of hours, therefore, will fall short of the annual mean by about one and a half per cent.

The term of third order vanishes at 3h. 37m., 7h. 37m., 11h. 37m., a.m. and p.m. Whence we may consider the observations made at (3h. 30m., 11h. 30m., 19h. 30m.) or (7h. 30m., 15h. 30m., 23h. 30m.) as giving the mean humidity of the year.

The fourth term vanishes at 2h. 16m., 5h. 16m., 8h. 16m., 11h. 16m., a.m. and p.m.; and, therefore, the observations of dry and wet bulb at (II., VIII., XIV., XX.) or (V., XI., XVII., XXIII.) will give the mean annual relative humidity with reasonable accuracy.

The epochs of humidity agree so closely with those of temperature, in each harmonic term, because the humidity curve is practically an inverted curve of temperature. The angular differences would, indeed, be exactly  $180^{\circ}$ , in each case, if the quantity of moisture in the air were constant, the departure from this angle arising out of the diurnal variation in the dew-point curve. The clear relationship between the corresponding harmonic terms of barometric pressure and dew-point has been mentioned elsewhere.\*

We may here conveniently summarise the best hours of observation indicated by theory:

1. For a single observation per diem, XX.; the temperature being combined with the maximum and minimum of the day, and the pressure increased by .01 inch—unless the barometer be read at XXI.

2. For two observations at homonymous hours:

Pressure... I., XIII., or VII., XIX.

Temperature... IV., XVI., or X., XXII.

Dew-point... I., XIII., or VII., XIX.

Humidity... IV., XVI., or X., XXII.

3. For three observations at intervals of eight hours:

Pressure... O., VIII., XVI., or IV., XII., XX.

Temperature... 23h. 30m., 7h. 30m., 15h. 30m.; or 3h. 30m., 11h. 30m., 19h. 30m.

Dew-point... O., VIII., XVI., or IV., XII., XX.

Humidity... 23h. 30m., 7h. 30m., 15h. 30m., or 3h. 30m., 11h. 30m., 19h. 30m.

\*"Elementary Synopsis, &c." *Trans. of the S.A. Phil. Soc. Vol. XIV. Part 2.*



the zero point, and the difficulty of ascertaining its amount. Now, while the annual normals of Table 1 have not been corrected for this source of error in any way, chiefly on account of the importance of introducing no mental bias into the harmonic formulæ, it seemed advisable to allow for it in the monthly and annual corrections of Tables 3, 4, 5; also an occasional *liberâ manû* correction has been inserted where it seemed wanted. Nevertheless, there still remains some little outstanding uncertainty in the corrections proper to dew-point and humidity, particularly during the hours before dawn in the winter. The three Tables in question, together with Table 2, give the corrections to be applied to the mean monthly or annual values of the respective elements of temperature of the air, temperature of the dew-point, ratio of humidity, and barometric pressure, for any hour in order to obtain the mean. A few examples will make their use clear.

At Philippolis the mean pressure at VIII. for the month of February, as deduced from observations made during a number of years, was found to be 25'537 inches; the correction to be applied to February observations at VIII., in order to obtain the mean hourly pressure of the month, is given in Table 2, as - '045 inch;

$$\therefore 25'537 - '045 = 25'492 \text{ inches.}$$

is the mean pressure required.

At Kimberley the mean pressure at XX. for the month of October, for certain years, was determined according to the register of the late G. J. Lee, to be 26'055 inches; the correction to be applied to October observations at XX., in order to obtain the mean of the month, is given in Table 2 as + '005 inch.

$$\therefore 26'055 + '005 = 26'060 \text{ inches,}$$

is the mean pressure required.

At Aliwal North the mean temperature of the air at VIII. for the month of November, as determined by five years' observations, is 64°·1; Table 3 gives the correction to be applied to November observations at VIII., in order to obtain the mean of the month, as + 0°·9;

$$\therefore 64^{\circ}\cdot 1 + 0^{\circ}\cdot 9 = 65^{\circ}\cdot 0,$$

is the mean temperature required for the period in question.

At Benaauwdehdsfontein the dew-point at XIV. for the year was found to be 44°·4 (Glaisher's Tables being used). Our Table 4 gives the correction to the temperature of the dew-point at XIV., in order to obtain the mean dew-point of the year, as - 0°·7;

$$\therefore 44^{\circ}\cdot 4 - 0^{\circ}\cdot 7 = 43^{\circ}\cdot 7, \text{ is the dew-point required.}$$

The corresponding humidity-ratio was found to be 34'3%; the proper correction given in Table 5 is + 19'7%;

$$\therefore 34'3 + 18'7 = 54'0\%,$$

is the humidity required.

Various combinations of hours are adopted in different countries for the purpose of deducing the mean temperature from second order observations:

In Sweden the formula is (or rather was, down to 1881, or later) for a Glaisher Screen,

$$\frac{1}{7} \cdot (\text{VIII.} + \text{XIV.} + 5 \cdot \text{XXI}).$$

At Gaboon,

$$\frac{1}{4} \cdot (\text{VII.} + \text{XIV.} + 2 \cdot \text{XXI}).$$

At Magdeburg,

$$\text{From May to August, } \frac{1}{4} \cdot (\text{VIII.} + \text{XX.} + \text{M} + \text{m}).$$

$$\text{From September to April, } \frac{1}{12} \cdot (5 \cdot \text{VIII.} + 5 \cdot \text{XX.} + 2 \cdot \text{XIV.});$$

and so on, in endless variety. In the British Islands, "the mean temperature of the month for the stations of the Royal Meteorological Society is determined by adding together the mean maximum and the mean minimum, and dividing the sum by 2";\* but in most months the resulting value is slightly greater than the hourly mean.

At the foot of Table 3 will be found the monthly and annual deviation of the mean hourly temperature from the mean minimum,  $m$ , the mean maximum,  $M$ , and from the average of these two  $\frac{1}{2}(m+M)$ . As an example, the average of the maximum and minimum shade temperature during June at Klerksdorp was found to be  $54^{\circ}0$ . The correction necessary to reduce the June values to the true mean is  $-1^{\circ}6$ ,

$$\therefore 54^{\circ}0 - 1^{\circ}6 = 52^{\circ}4.$$

is the mean June temperature required.

Kaemtz procured a mean temperature by multiplying the mean range  $M - m$  by certain monthly numerical co-efficients, and adding the result to the minimum. Thus:

$$T = m + K (M - m),$$

where the co-efficient,  $K$ , changes in value from one month to another. The monthly values of  $K$ , for Kenilworth, together with some comparative numbers for the Northern Hemisphere, are given in Table 15. Sir John Herschel's account of such factors deserves to be put on record as being perhaps the one hopelessly unintelligible sentence he ever wrote:—"Kaemtz recommends (from a discussion of the observations at Padua and Fort Leith . . . ) to employ the formula

$$m + \frac{1}{36} \cdot (M - m) \cdot (5^{\circ}076 + x)$$

where  $x$  is a variable co-efficient, fluctuating from  $0^{\circ}366$  in December to  $0^{\circ}560$  in August; and which may, for the purpose in question, be taken quite near enough at  $0^{\circ}44 \sin (\theta + 120^{\circ})$ ,  $\theta$  being the sun's mean longitude."

\*Marriott, "Hints to Meteorological Observers," p. 30. See also some remarks by Scott, "Instructions in the use of Meteorological Instruments," p. 79. Glaisher's elaborate "Diurnal Range Tables" should also be consulted. Hann notices the approach of the average extreme temperature,  $\frac{1}{2}(m+M)$ , to the true mean in October and November:—"Der Sprung in den Differenzen vom September zum Oktober ist sehr merkwürdig. . . ."

Now these numbers apply in particular to the reduction of monthly averages. But they may be converted into a formula which will apply also to the reduction of daily averages, when the period is long enough. A suitable formula for Kenilworth is:

$$K = .462 + .025 \sin (n30^\circ + 162^\circ.5) - .007 \sin (n60^\circ + 214^\circ.5),$$

counting from the middle of January. Whence, if we determine the mean minimum temperature,  $m$ , and the mean maximum,  $M$ , of any day in the year, we can determine the mean temperature,  $T$ , of the day from the formula:

$$T = m + K (M - m),$$

where  $K$  has the value given above.

Example: For the ten years 1888-1897, on March 1st, at Kimberley, according to the Lee register,  $M = 86^\circ.6$ ,  $m = 60^\circ.0$ . With sufficient accuracy we may put  $n = 1.5$ . Therefore

$$T = 60^\circ.0 + 26^\circ.6 \{0.462 - 0.025 + 0.462 - 0.007 + 0.824\} = 71^\circ.8.$$

Since in our example the value of  $\frac{1}{2} (M + m)$  is  $73^\circ.3$ , the difference between this and the computed mean is  $1^\circ.5$ , agreeing, therefore, with the tabular correction for March on the last line but one of Table 3.

Hitherto we have been discussing mean conditions under a sky whose average cloudiness would fall somewhere between 20% and 30%. The tables at the end, Nos. 6—13, give, in addition, material applying to "cloudy" skies whose average cloudiness exceeds 50%, and to "clear" skies whose average cloudiness does not reach even 5%. The latter is only likely to be of occasional use in very special cases, chiefly in winter. For probably no station in the world has less cloud than Kimberley. But the former may apply to some extent to such places as Queenstown, Umtata, or the Katberg Sanatorium, or even Uitenhage. The secular change whereby temperature and pressure tend to rise, dew-point and humidity to fall under clear skies (and of course vice-versa under cloudy skies), has not been corrected for. Before computing the harmonic terms of the different elements, however, the annual curves were reduced to re-enter. It is doubtful, nevertheless, whether some small extraneous error is not thereby introduced.\*

Kaemtz's factors for clear and for cloudy skies are shewn in Table 15.

A word of explanation may be acceptable concerning the Tables 6—13.

First, the values under clear skies were picked out one by one from the registers, and arranged in monthly sets. The same

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\*In the Annual Normals for clear and for cloudy skies, in Table I., instrumental errors have been corrected.

laborious process could be used in getting the values under cloudy skies, albeit there are other and shorter ways. The most suitable seems to be :

At any hour in a given month

Let  $p$  be the pressure (say) under cloudy skies :

$P$  the pressure under clear skies :

$\pi$  the pressure under all skies.

Let there be  $a$  cloudy days in the month and  $A$  clear ;

so that  $k = a + A$ .

Then  $ap + AP = (a + A) \pi$

$\therefore ap + (k - a) P = k \pi$

$\therefore p = P - (k - a) (P - \pi)$ .

This simple formula is so powerful withal that given a five years full register, and the values under clear skies, then the monthly sets of hourly values of any element—temperature, pressure, humidity, etc.—may be obtained completely in about two hours. Here, again, the yearly means are the simple average of the monthly sets.

There are a great many more clear days in winter than in summer, so that if we were to consider the year of clear or cloudy days to be the average of the days, then the annual mean diurnal curve under clear skies would display winter characteristics, while the curve under cloudy skies would display those of summer. By considering the yearly means to be the average of the monthly sets we eliminate the effect of the unequal distribution of days. And, therefore, we get a representation of a very clear or a very cloudy year. But of course the mean year will not be the arithmetic mean of the two components.

Table 14 gives a comparative view of the harmonic constituents as far as the fourth term.

TABLE I.

	Annual Normals.				Annual Normals for Clear Skies.				Annual Normals for Cloudy Skies.			
	Pressure.	Temperature.	Dew Point.	Humidity.	Pressure.	Temperature.	Dew Point.	Humidity.	Pressure.	Temperature.	Dew Point.	Humidity.
	Inch.			%	Inch.			%	Inch.			%
O.	26.143	56.3	42.7	63.0	26.151	54.4	38.9	58.4	26.129	57.6	45.2	65.8
I.	.139	55.2	42.8	65.6	.149	53.1	39.0	61.3	.125	56.5	45.2	67.7
II.	.135	54.0	42.6	68.0	.146	51.8	38.7	63.1	.119	55.6	45.2	70.0
III.	.132	53.2	42.4	69.1	.145	50.6	38.4	65.1	.116	54.8	45.1	71.6
IV.	.134	52.4	42.2	70.4	.148	49.6	38.2	67.3	.118	54.2	45.0	73.3
V.	.141	51.5	42.3	72.5	.156	48.5	38.0	68.8	.124	53.5	45.0	74.8
VI.	.153	51.6	42.6	73.3	.169	48.6	38.4	69.7	.136	53.6	45.4	75.7
VII.	.165	53.7	43.4	70.6	.181	51.3	39.4	66.8	.147	55.7	46.1	72.9
VIII.	.175	59.1	44.5	60.8	.192	57.8	40.7	55.7	.157	60.4	47.0	64.0
IX.	.179	64.8	45.3	52.1	.196	64.0	41.7	46.4	.160	65.3	47.6	55.9
X.	.176	68.9	45.4	45.6	.194	68.8	41.9	39.7	.156	68.9	47.6	49.6
XI.	.165	72.3	45.3	40.7	.184	72.5	41.7	34.9	.145	72.1	47.4	44.5
Noon.	.145	74.6	45.0	37.4	.166	75.0	41.4	31.6	.125	74.2	47.1	41.1
XIII.	.124	76.3	44.6	35.1	.146	77.0	40.9	29.0	.104	75.7	46.8	38.8
XIV.	.105	76.9	44.4	34.3	.126	78.2	40.7	27.7	.083	76.1	46.5	38.4
XV.	.094	76.8	44.0	34.2	.115	78.6	40.3	26.8	.074	75.7	46.1	38.5
XVI.	.089	75.7	43.8	35.2	.109	77.9	40.0	27.3	.069	74.5	45.9	39.9
XVII.	.091	72.5	44.5	40.5	.110	74.3	40.6	32.6	.071	71.6	46.6	45.0
XVIII.	.100	68.0	44.4	46.5	.117	69.0	40.5	39.0	.081	67.8	46.5	50.6
XIX.	.113	64.4	44.2	51.4	.129	64.5	40.4	44.0	.095	64.7	46.5	55.5
XX.	.127	62.2	43.8	54.1	.142	61.8	39.7	46.5	.110	62.8	46.3	58.3
XXI.	.137	60.3	43.3	56.6	.151	59.8	38.9	48.6	.119	60.9	46.1	61.2
XXII.	.143	58.8	43.1	58.8	.157	58.0	38.6	50.8	.126	59.6	45.9	63.3
XXIII.	.144	57.4	42.9	60.6	.159	56.6	38.3	52.6	.128	58.5	45.7	65.2
Day.	26.136	63.2	43.7	54.0	26.152	62.6	39.8	48.1	26.117	63.8	46.2	57.6
m.	...	49.8	...	...	...	47.0	...	...	...	51.7	...	...
M.	...	78.8	...	...	...	79.5	...	...	...	78.2	...	...
4(M+m).	...	64.3	...	...	...	63.3	...	...	...	65.0	...	...
M-m.	...	29.0	...	...	...	32.5	...	...	...	26.6	...	...

TABLE 2.—Corrected barometer pressure in a foot vacuum for Jan.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
O.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
I.	— .000	— .007	— .008	— .000	— .005	— .003	— .004	— .010	— .010	— .009	— .007	— .007	— .007
II.	— .004	— .004	— .005	— .003	— .003	— .002	— .003	— .007	— .005	— .002	— .003	— .002	— .003
III.	+ .003	— .001	+ .000	+ .002	+ .001	+ .000	+ .001	— .002	+ .003	+ .003	+ .000	+ .002	+ .001
IV.	+ .004	+ .002	+ .004	+ .008	+ .005	+ .002	+ .003	+ .001	+ .008	+ .005	— .001	+ .001	+ .004
V.	— .002	— .000	+ .004	+ .009	+ .007	+ .003	+ .005	+ .002	+ .004	— .001	— .007	— .006	+ .002
VI.	— .013	— .009	— .002	+ .004	+ .003	+ .001	+ .002	— .003	— .004	— .012	— .010	— .017	+ .005
VII.	— .028	— .022	— .015	— .005	— .005	— .007	— .006	— .012	— .018	— .028	— .034	— .032	— .017
VIII.	— .030	— .030	— .026	— .017	— .016	— .017	— .017	— .023	— .033	— .040	— .045	— .043	— .020
IX.	— .043	— .045	— .038	— .034	— .031	— .031	— .029	— .037	— .045	— .046	— .050	— .046	— .030
X.	— .041	— .045	— .042	— .040	— .039	— .040	— .039	— .043	— .048	— .047	— .046	— .043	— .043
XI.	— .036	— .041	— .041	— .038	— .039	— .042	— .042	— .043	— .042	— .038	— .039	— .036	— .040
XII.	— .028	— .030	— .031	— .031	— .031	— .032	— .033	— .033	— .028	— .033	— .026	— .026	— .020
XIII.	— .011	— .014	— .015	— .012	— .010	— .012	— .012	— .010	— .004	— .003	— .007	— .008	— .009
XIV.	+ .005	+ .003	+ .005	+ .012	+ .012	+ .010	+ .012	+ .015	+ .019	+ .016	+ .013	+ .009	+ .012
XV.	+ .026	+ .025	+ .025	+ .028	+ .030	+ .029	+ .029	+ .035	+ .040	+ .037	+ .035	+ .030	+ .031
XVI.	+ .041	+ .040	+ .037	+ .034	+ .037	+ .034	+ .036	+ .045	+ .049	+ .047	+ .049	+ .042	+ .042
XVII.	+ .054	+ .050	+ .044	+ .037	+ .038	+ .034	+ .039	+ .045	+ .051	+ .051	+ .057	+ .057	+ .047
XVIII.	+ .056	+ .054	+ .043	+ .035	+ .032	+ .030	+ .035	+ .042	+ .045	+ .048	+ .056	+ .058	+ .045
XIX.	+ .045	+ .044	+ .037	+ .027	+ .023	+ .021	+ .026	+ .032	+ .035	+ .038	+ .048	+ .046	+ .036
XX.	+ .028	+ .031	+ .026	+ .016	+ .011	+ .013	+ .016	+ .018	+ .021	+ .024	+ .032	+ .033	+ .023
XXI.	+ .016	+ .015	+ .009	+ .002	+ .001	+ .001	+ .007	+ .005	+ .001	+ .005	+ .014	+ .016	+ .009
XXII.	+ .002	+ .003	— .002	— .006	— .004	+ .001	— .000	— .003	— .008	— .002	+ .003	+ .002	— .001
XXIII.	— .010	— .005	— .007	— .010	— .007	— .003	— .005	— .010	— .012	— .008	— .007	— .008	— .007
XXIV.	— .012	— .009	— .010	— .010	— .007	— .004	— .006	— .011	— .012	— .009	— .009	— .011	— .008

TABLE 3.—Corrections to be applied to the Hourly Temperatures in order to obtain the Mean.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
O.	+6.4	+6.6	+6.1	+5.7	+6.2	+6.0	+6.9	+7.6	+7.9	+7.6	+8.4	+7.5	+6.9
I.	+7.6	+7.7	+7.8	+6.7	+7.4	+7.1	+8.0	+8.8	+9.2	+8.9	+9.8	+8.8	+8.0
II.	+8.6	+8.8	+7.9	+7.5	+8.2	+8.2	+8.0	+9.0	+10.3	+10.1	+11.1	+9.9	+9.0
III.	+9.6	+9.7	+8.5	+7.3	+9.1	+9.2	+9.7	+10.8	+11.3	+11.2	+12.3	+10.9	+10.0
IV.	+10.6	+10.4	+9.0	+9.0	+9.8	+10.0	+10.4	+11.6	+12.3	+12.1	+13.5	+11.9	+10.9
V.	+11.4	+11.1	+9.7	+9.7	+10.6	+10.7	+11.0	+12.4	+13.3	+13.0	+14.5	+12.9	+11.7
VI.	+11.0	+11.5	+10.4	+10.3	+11.3	+11.3	+11.5	+13.3	+13.9	+12.6	+12.2	+10.7	+11.6
VII.	+6.9	+8.1	+8.6	+9.8	+11.7	+11.9	+12.1	+13.1	+11.6	+7.6	+6.5	+6.1	+9.5
VIII.	+2.2	+3.0	+3.0	+3.8	+6.3	+7.3	+7.8	+6.2	+3.7	+1.6	+0.9	+1.4	+3.9
IX.	+1.7	+1.3	+1.3	+1.4	+0.8	+0.2	+0.2	+0.7	+1.7	+2.7	+3.2	+2.6	+1.6
X.	+5.1	+5.1	+5.2	+5.3	+5.7	+5.7	+5.1	+5.7	+6.4	+6.4	+6.7	+6.0	+5.7
XI.	+8.0	+8.4	+7.7	+8.6	+9.4	+9.7	+9.3	+9.8	+10.0	+9.4	+9.7	+9.1	+9.1
Noon	+10.2	+10.3	+9.9	+10.8	+12.1	+12.3	+12.1	+12.6	+12.5	+11.2	+11.5	+11.0	+11.4
XIII.	+11.3	+11.8	+11.2	+12.2	+13.9	+14.1	+14.3	+14.8	+14.5	+12.8	+13.0	+12.4	+13.1
XIV.	+11.3	+12.7	+11.9	+12.5	+14.8	+15.1	+15.3	+15.9	+15.3	+13.5	+13.6	+12.2	+13.7
XV.	+10.8	+12.3	+11.7	+12.3	+14.8	+15.1	+15.6	+16.1	+15.4	+13.3	+13.7	+11.9	+13.6
XVI.	+10.1	+11.4	+11.0	+11.3	+13.5	+13.5	+14.3	+15.2	+14.3	+12.3	+12.7	+11.0	+12.5
XVII.	+8.5	+9.4	+8.8	+7.7	+8.1	+7.2	+8.9	+11.3	+11.4	+9.9	+10.3	+9.6	+9.3
XVIII.	+6.6	+6.2	+4.8	+2.7	+2.7	+2.3	+3.2	+4.5	+5.7	+5.5	+6.9	+6.5	+4.8
XIX.	+2.3	+2.0	+1.0	+0.3	+0.3	+0.1	+0.5	+1.0	+1.6	+1.5	+2.4	+2.2	+1.2
XX.	+0.6	+0.8	+1.0	+1.3	+1.5	+1.5	+1.1	+1.0	+0.9	+0.8	+0.6	+0.7	+1.0
XXI.	+2.7	+2.6	+2.7	+2.9	+3.3	+2.9	+2.7	+3.0	+3.3	+2.8	+3.0	+2.8	+2.9
XXII.	+4.1	+4.2	+3.9	+4.0	+4.5	+4.0	+4.4	+4.8	+5.0	+4.6	+4.6	+4.4	+4.4
XXIII.	+5.3	+5.3	+5.1	+5.1	+5.4	+5.0	+5.6	+6.0	+6.3	+6.1	+6.2	+6.0	+5.8
m.	+12.7	+12.4	+11.1	+11.2	+12.7	+12.8	+13.2	+14.8	+15.1	+14.7	+15.8	+14.1	+13.4
M.	+14.7	+15.1	+14.1	+14.2	+15.8	+15.9	+16.3	+17.1	+16.9	+15.4	+16.0	+15.3	+15.6
‡ (m+M).	+1.0	+1.3	+1.5	+1.5	+1.5	+1.6	+1.5	+1.1	+0.9	+0.4	+0.1	+0.6	+1.1
M-m.	+46.6	+46.6	+43.9	+37.1	+26.2	+20.4	+19.3	+22.6	+29.1	+35.4	+38.7	+45.3	+34.2

TABLE 4.—Corrections to be applied to the Hourly Temperatures of the Dew Point in order to obtain the Mean.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
O.	+0.1	+0.4	-0.5	+0.5	+1.6	+1.7	+2.2	+2.1	+1.7	+0.9	+1.2	+0.2	+1.0
I.	0.0	0.0	-0.3	+0.6	+1.5	+2.0	+2.3	+2.0	+1.5	+0.8	+1.1	0.0	+0.9
II.	-0.1	-0.2	-0.3	+0.9	+1.8	+2.3	+2.6	+2.3	+1.7	+0.9	+1.0	0.0	+1.1
III.	-0.2	-0.1	-0.1	+1.2	+2.3	+2.9	+3.0	+2.6	+2.0	+1.1	+0.6	0.0	+1.3
IV.	-0.1	+0.2	+0.2	+1.3	+2.5	+3.1	+3.3	+3.0	+2.4	+1.4	+0.7	0.0	+1.5
V.	-0.4	-0.2	+0.3	+1.4	+2.5	+3.3	+3.9	+3.2	+2.6	+1.2	+0.5	-0.4	+1.4
VI.	-1.3	-0.9	+0.4	+1.5	+2.6	+3.6	+4.2	+3.2	+2.6	+0.4	-0.9	-1.8	+1.1
VII.	-2.1	-1.6	-0.4	+1.1	+1.9	+3.0	+3.8	+2.5	+0.8	-0.9	-2.0	-2.4	+0.3
VIII.	-1.5	-1.7	-1.1	-0.7	+0.2	+1.3	+1.7	0.0	-0.7	-1.5	-2.4	-2.3	-0.8
IX.	-1.6	-1.7	-1.1	-1.2	-1.4	-1.0	-0.9	-1.5	-1.7	-2.1	-2.3	-2.0	-1.6
X.	-0.9	-1.1	-0.9	-1.0	-2.0	-2.3	-2.2	-2.4	-2.2	-1.9	-1.6	-1.4	-1.7
XI.	-0.2	-0.5	-0.7	-0.9	-2.6	-2.0	-2.9	-2.8	-2.0	-1.7	-1.0	-0.4	-1.6
Noon.	+0.4	+0.3	0.0	-0.5	-2.3	-3.1	-3.3	-2.8	-2.0	-1.2	-0.7	0.0	-1.3
XIII.	+0.8	+0.9	+0.7	+0.1	-1.8	-2.9	-3.3	-2.7	-1.5	-0.9	-0.2	+0.8	-0.9
XIV.	+1.2	+1.1	+1.2	-0.1	-1.5	-2.8	-3.3	-2.4	-1.6	-0.4	0.0	+1.0	-0.7
XV.	+1.1	+1.5	+1.5	+0.4	-1.1	-2.5	-2.9	-2.0	-0.9	+0.1	+0.4	+1.5	-0.3
XVI.	+1.4	+2.1	+2.0	+0.2	-1.0	-2.6	-2.8	-1.8	-0.8	+0.5	+0.9	+1.9	-0.1
XVII.	+1.6	+1.6	+1.1	-1.3	-2.9	-4.0	-4.3	-2.8	-1.2	+0.3	+1.0	+2.0	-0.8
XVIII.	+1.4	+0.9	0.0	-1.6	-1.9	-2.0	-2.6	-2.3	-1.5	-0.2	+0.9	+1.7	-0.7
XIX.	+0.4	-0.1	-0.8	-1.0	+0.7	-0.8	-1.3	-1.0	-0.7	+0.3	0.0	+0.6	-0.5
XX.	0.0	-0.4	-0.6	-0.5	-0.2	+0.1	-0.2	0.0	-0.1	+0.3	+0.1	+0.5	-0.1
XXI.	-0.1	-0.1	-0.4	-0.1	+0.7	+0.6	+0.6	+0.8	+0.8	+0.8	+0.7	+0.6	+0.4
XXII.	+0.2	-0.1	-0.3	+0.3	+1.3	+1.2	+1.2	+1.1	+1.1	+1.0	+0.8	+0.5	+0.6
XXIII.	+0.3	+0.1	-0.5	+0.7	+1.7	+1.5	+1.5	+1.7	+1.4	+0.9	+1.0	+0.5	+0.8

TABLE 5.—Corrections to be applied to the Hourly Ratios of Humidity in order to obtain the Mean.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	%	%	%	%	%	%	%	%	%	%	%	%	%
O.	-9.5	-8.7	-12.4	-10.3	-8.2	7.7	8.3	7.6	8.4	-9.3	8.3	-9.9	-9.0
I.	-11.1	-11.5	-14.2	-12.6	-11.2	-9.6	-10.6	-11.0	-11.4	-11.9	10.8	-12.5	-11.6
II.	-13.2	-14.4	-16.2	-13.7	-12.5	-11.8	-12.1	-12.9	-12.9	-13.7	13.2	-13.8	-13.4
III.	-15.7	-16.1	-17.8	-15.5	-13.5	-12.8	-12.7	-14.1	-14.8	-15.8	-16.3	-16.6	-15.1
IV.	-17.5	-17.3	-19.0	-17.5	-15.2	-14.7	-13.8	-15.6	-16.3	-17.7	19.4	-18.9	-17.0
V.	-19.9	-19.3	-20.0	-18.6	-17.0	-16.1	-14.2	-16.5	-17.6	-19.6	21.3	-21.5	-18.5
VI.	-20.9	-21.8	-21.3	-20.1	-18.6	-17.7	-15.3	-18.8	-19.3	-20.0	19.4	-19.3	-19.3
VII.	-13.3	-15.4	-18.6	-20.9	-21.6	-19.4	-17.6	-20.4	-18.0	-12.3	10.3	-10.8	-16.6
VIII.	-3.3	-5.4	-15.9	-8.4	-11.7	-12.2	-11.6	-9.8	-5.6	-2.5	2.4	-2.7	-6.8
IX.	+2.7	+1.8	+3.3	+2.7	+0.7	+0.2	-0.4	+0.5	+1.7	+3.0	+3.2	+3.2	+1.9
X.	+8.8	+8.4	+9.8	+10.6	+8.4	+8.2	+7.1	+7.0	+7.3	+8.3	+8.2	+6.3	+8.4
XI.	+13.3	+13.3	+14.9	+16.4	+13.6	+14.1	+12.7	+12.1	+12.2	+12.0	+12.0	+13.2	+13.3
Noon.	+16.5	+16.3	+19.0	+20.6	+17.1	+17.9	+16.7	+15.6	+15.2	+14.2	+13.9	+15.5	+16.6
XIII.	+17.7	+18.7	+21.1	+23.7	+20.9	+20.6	+19.6	+18.4	+17.7	+16.2	+15.6	+17.4	+18.9
XIV.	+17.6	+19.3	+22.9	+23.1	+22.4	+22.0	+20.9	+19.0	+18.0	+17.4	+16.1	+16.9	+19.7
XV.	+16.5	+19.0	+22.6	+22.9	+23.2	+22.6	+21.7	+20.6	+18.9	+17.5	+16.3	+16.6	+19.8
XVI.	+15.9	+18.7	+22.4	+21.0	+21.6	+20.4	+20.1	+19.8	+18.1	+16.6	+15.9	+15.7	+18.8
XVII.	+14.3	+15.5	+18.4	+13.4	+11.0	+7.9	+9.7	+14.3	+14.7	+14.1	+13.6	+14.6	+13.5
XVIII.	+11.7	+10.6	+10.9	+4.1	+3.5	+2.4	+2.6	+15.7	+7.9	+8.4	+10.5	+11.4	+7.5
XIX.	+5.0	+4.0	+2.8	+0.1	+1.1	-0.1	0.0	+2.3	+3.3	+3.3	+4.7	+4.9	+2.6
XX.	+0.6	-0.4	-0.9	-2.1	-0.7	-0.9	-0.8	+0.8	+0.4	+1.0	+1.0	+1.1	-0.1
XXI.	-3.4	-2.9	-4.3	-5.0	-3.2	-2.8	-2.4	-1.3	-2.0	-1.2	-1.0	-1.9	-2.6
XXII.	-4.8	-5.3	-7.0	-6.6	-4.8	-4.1	-5.0	-4.1	-4.1	-3.8	-3.3	-4.2	-4.8
XXIII.	-6.9	-6.6	-10.1	-8.2	-5.8	-5.8	-6.6	-5.4	-6.0	-6.1	-5.3	-6.8	-6.6

TABLE 6. Corrections to be applied to the Hourly Pressures under Clear Skies in order to obtain the Mean.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
O.	in. +.005	in. -.003	in. +.002	in. +.004	in. +.001	in. +.005	in. +.006	in. +.003	in. +.014	in. +.004	in. +.003	in. +.004	in. +.001
I.	+.008	-.001	+.005	+.004	+.002	+.006	+.005	+.001	-.001	+.007	+.006	+.007	+.003
II.	+.011	+.002	+.007	+.007	+.005	+.006	+.003	+.003	+.002	+.011	+.008	+.010	+.006
III.	+.009	+.003	+.009	+.011	+.008	+.007	+.002	+.005	+.002	+.011	+.008	+.008	+.007
IV.	+.002	-.003	+.006	+.012	+.009	+.008	+.000	+.005	-.001	+.004	-.001	+.000	+.004
V.	-.011	-.011	-.001	+.005	+.006	+.005	+.004	+.001	+.009	+.008	+.014	+.012	+.004
VI.	-.027	-.026	-.013	-.003	+.002	+.005	+.011	+.012	+.023	+.025	+.031	-.030	-.017
VII.	-.041	-.040	-.023	-.016	+.013	-.015	+.023	+.024	+.037	+.039	+.042	+.041	+.039
VIII.	-.045	-.049	-.037	-.033	-.020	-.028	-.033	+.038	+.048	+.047	-.048	+.046	+.040
IX.	-.044	-.049	-.041	-.040	-.038	-.039	+.043	+.045	+.051	+.049	+.047	+.045	+.044
X.	-.040	-.044	-.040	-.038	-.040	-.041	+.046	+.045	+.045	+.043	+.042	+.040	+.042
XI.	-.032	-.033	-.032	-.032	-.031	-.032	+.035	-.035	-.030	+.029	+.031	+.032	+.032
XII.	-.018	-.017	-.017	-.015	-.012	+.013	+.015	+.014	+.006	+.010	-.015	+.017	+.014
XIII.	-.002	+.001	+.001	+.006	+.010	+.008	+.008	+.012	+.018	+.009	+.004	+.002	+.006
XIV.	+.009	+.020	+.019	+.024	+.027	+.026	+.028	+.031	+.039	+.030	+.026	+.018	+.026
XV.	+.034	+.036	+.030	+.029	+.032	+.032	+.037	+.041	+.048	+.042	+.040	+.035	+.037
XVI.	+.048	+.048	+.036	+.030	+.033	+.031	+.038	+.042	+.052	+.046	+.050	+.050	+.043
XVII.	+.054	+.055	+.030	+.029	+.028	+.027	+.036	+.039	+.047	+.043	+.050	+.052	+.042
XVIII.	+.046	+.049	+.032	+.023	+.020	+.019	+.020	+.029	+.039	+.035	+.041	+.046	+.035
XIX.	+.032	+.037	+.025	+.014	+.010	+.009	+.020	+.018	+.026	+.019	+.020	+.032	+.023
XX.	+.017	+.024	+.007	+.003	+.001	+.001	+.012	+.005	+.008	+.002	+.012	+.018	+.010
XXI.	+.004	+.012	-.001	-.005	-.004	-.004	+.006	+.003	+.000	+.005	+.001	+.002	+.001
XXII.	+.008	+.002	+.005	+.009	+.007	+.008	+.002	+.003	+.002	+.009	+.007	+.009	+.005
XXIII.	-.012	-.001	-.008	+.008	-.007	-.009	+.001	-.009	-.002	+.011	-.009	-.012	-.007

TABLE 7.—Corrections to be applied to the Hourly Pressures under Cloudy Skies in order to obtain the Mean

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
O.	-.015	-.010	-.012	-.011	-.017	-.005	-.008	-.014	-.012	-.016	-.010	-.012	-.012
I.	-.009	-.006	-.009	-.006	-.014	-.004	-.007	-.010	-.007	-.007	-.006	-.006	-.008
II.	-.001	-.003	-.003	-.001	-.008	+.001	+.000	+.003	+.001	+.001	+.002	+.002	+.002
III.	+.002	+.000	+.002	+.006	+.003	+.002	+.003	+.001	+.007	+.002	+.005	+.002	+.001
IV.	+.004	+.001	+.003	+.007	+.000	+.003	+.005	+.003	+.004	+.003	+.009	+.009	+.001
V.	.014	+.000	+.003	+.003	+.003	+.002	+.006	+.003	+.004	+.014	+.021	+.010	+.007
VI.	.029	+.024	+.016	+.007	+.011	+.005	+.003	+.010	+.018	+.029	+.034	+.033	+.019
VII.	.039	+.035	+.027	+.018	+.022	+.015	+.013	+.022	+.034	+.040	+.045	+.044	+.030
VIII.	+.043	+.044	+.039	+.035	+.036	+.031	+.025	+.036	+.045	+.046	+.050	+.046	+.040
IX.	+.040	+.044	+.043	+.040	+.043	+.039	+.035	+.040	+.048	+.046	+.045	+.043	+.043
X.	+.035	+.040	+.042	+.048	+.040	+.041	+.041	+.040	+.042	+.035	+.037	+.035	+.039
XI.	+.027	+.029	+.031	+.031	+.031	+.032	+.030	+.030	+.028	+.020	+.023	+.024	+.028
Noon.	+.009	+.013	+.014	+.011	+.008	+.011	+.007	+.005	+.003	+.001	+.002	+.004	+.008
XIII.	+.007	+.004	+.006	+.014	+.014	+.012	+.018	+.019	+.020	+.020	+.019	+.013	+.013
XIV.	+.028	+.026	+.027	+.030	+.033	+.030	+.033	+.040	+.041	+.041	+.046	+.044	+.044
XV.	+.043	+.041	+.040	+.036	+.043	+.034	+.037	+.050	+.050	+.053	+.046	+.044	+.043
XVI.	+.056	+.050	+.047	+.040	+.044	+.035	+.041	+.049	+.050	+.054	+.060	+.059	+.048
XVII.	+.056	+.054	+.046	+.037	+.039	+.029	+.036	+.044	+.045	+.051	+.058	+.060	+.046
XVIII.	+.044	+.044	+.039	+.029	+.028	+.019	+.027	+.034	+.034	+.040	+.049	+.046	+.036
XIX.	+.026	+.030	+.026	+.017	+.014	+.011	+.015	+.016	+.019	+.027	+.031	+.033	+.022
XX.	+.015	+.013	+.010	+.002	+.005	+.001	+.005	+.003	+.000	+.007	+.012	+.015	+.007
XXI.	+.001	+.001	+.003	+.007	+.000	+.002	+.001	+.005	+.010	+.000	+.001	+.002	+.002
XXII.	-.011	-.006	-.008	-.011	-.003	-.006	-.008	-.014	-.015	-.007	-.010	-.008	-.009
XXIII.	-.012	-.010	-.011	-.012	-.003	-.007	-.009	-.015	-.015	-.008	-.012	-.011	-.011

TABLE 8.—Corrections to be applied to the Hourly Temperatures under Clear Skies in order to obtain the Mean.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
O.	+8.7	+8.5	+7.7	+6.6	+6.8	+6.6	+8.1	+8.4	+9.0	+9.1	+9.2	+8.7	+8.2
I.	+9.0	+9.9	+9.2	+7.8	+7.9	+7.7	+9.2	+9.7	+10.4	+10.5	+10.7	+10.6	+9.5
II.	+11.1	+11.4	+10.2	+8.9	+8.9	+8.0	+10.2	+10.7	+12.2	+12.2	+12.4	+12.0	+10.8
III.	+12.0	+12.5	+11.1	+10.1	+9.8	+10.1	+11.1	+11.0	+13.4	+13.6	+13.9	+13.8	+12.0
IV.	+13.4	+13.4	+12.0	+11.1	+10.7	+10.9	+11.9	+13.0	+14.5	+14.7	+15.3	+15.3	+13.0
V.	+14.7	+14.3	+13.1	+12.0	+11.6	+11.8	+12.6	+13.8	+15.6	+16.0	+16.6	+16.3	+14.1
VI.	+14.1	+14.4	+13.9	+12.9	+12.3	+12.6	+13.1	+14.9	+16.5	+15.3	+14.2	+13.9	+14.0
VII.	+8.9	+10.4	+11.8	+11.8	+12.0	+13.1	+13.8	+14.9	+13.5	+9.1	+7.4	+8.0	+11.3
VIII.	+3.4	+4.2	+4.0	+5.3	+7.0	+8.1	+9.0	+6.8	+3.7	+2.0	+1.3	+2.3	+4.8
IX.	+0.8	0.8	+1.7	+1.5	+1.2	0.6	+0.1	+1.1	+2.1	+2.0	+3.0	+2.0	+1.4
X.	+4.6	+5.2	+6.2	+6.2	+6.7	+6.4	+5.9	+6.6	+7.5	+6.0	+6.6	+6.0	+6.2
XI.	+7.9	+8.8	+9.4	+9.8	+10.6	+10.8	+10.6	+10.7	+11.1	+10.0	+9.7	+9.1	+9.0
Noon.	+10.3	+11.2	+11.8	+12.0	+13.4	+13.5	+13.8	+14.0	+14.0	+12.3	+11.7	+11.6	+12.4
XIII.	+12.2	+13.3	+13.7	+13.9	+15.2	+15.4	+16.3	+16.2	+16.1	+14.3	+13.5	+13.3	+14.4
XIV.	+13.7	+14.6	+14.7	+14.9	+16.2	+16.4	+17.4	+17.4	+17.2	+15.4	+14.6	+14.5	+15.6
XV.	+14.5	+14.4	+15.3	+15.2	+16.2	+16.6	+17.8	+17.9	+17.5	+15.9	+15.3	+15.1	+16.0
XVI.	+14.5	+15.1	+14.8	+14.8	+15.0	+15.1	+16.8	+16.8	+16.6	+15.3	+14.7	+14.7	+15.3
XVII.	+12.8	+13.3	+12.2	+10.3	+8.6	+7.9	+10.5	+12.5	+13.7	+12.8	+12.9	+13.2	+11.7
XVIII.	+10.2	+10.3	+6.7	+3.2	+2.4	+2.4	+3.8	+4.8	+6.6	+7.6	+8.7	+9.8	+6.4
XIX.	+4.5	+4.2	+1.4	+0.5	+0.3	+0.2	+0.6	+1.1	+1.8	+2.4	+3.1	+4.5	+1.9
XX.	+0.6	0.0	+0.9	+1.5	+2.3	+1.9	+1.0	+1.2	+1.0	+0.3	+0.1	+0.5	+0.8
XXI.	+1.9	+2.4	+2.9	+3.0	+3.7	+3.3	+2.9	+3.2	+3.5	+2.4	+2.4	+2.0	+2.8
XXII.	+3.8	+4.5	+4.5	+4.4	+5.2	+4.5	+4.9	+5.1	+5.3	+4.4	+4.4	+4.0	+4.6
XXIII.	+5.7	+5.7	+5.7	+5.4	+6.1	+5.6	+6.2	+6.4	+6.6	+6.3	+6.2	+5.9	+6.0
m.	+15.9	+15.5	+14.4	+13.7	+13.7	+13.7	+14.5	+16.1	+17.3	+17.2	+17.5	+17.1	+15.6
M.	+15.5	+16.3	+15.9	+15.9	+16.9	+17.6	+18.2	+18.4	+18.3	+17.2	+16.4	+16.1	+16.9
} (M+m).	+0.2	+0.4	+0.8	+1.1	+1.6	+2.0	+1.8	+1.1	+0.5	0.0	+0.5	+0.5	+0.7
	+43.7	+42.8	+38.9	+31.1	+23.4	+16.7	+15.5	+19.9	+21.4	+30.1	+34.7	+41.4	+30.1

TABLE 9.—Corrections to be applied to the Hourly Temperatures under Cloudy Skies in order to obtain the Mean.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
O.	+5.5	+6.0	+5.5	+5.3	+5.5	+5.2	+5.0	+6.6	+7.2	+6.7	+7.9	+7.0	+6.2
I.	+6.7	+7.0	+6.0	+6.2	+6.8	+6.3	+6.1	+7.7	+8.5	+8.0	+9.2	+8.1	+7.3
II.	+7.8	+8.2	+7.0	+6.8	+7.6	+7.2	+6.8	+8.7	+9.2	+9.1	+10.4	+8.9	+8.2
III.	+8.7	+8.8	+7.5	+7.4	+8.2	+8.2	+7.5	+9.4	+10.1	+9.9	+11.3	+9.9	+9.0
IV.	+9.5	+9.4	+7.8	+8.0	+8.7	+8.8	+8.0	+10.0	+10.9	+10.7	+12.3	+10.6	+9.6
V.	+10.1	+10.0	+8.5	+8.6	+9.4	+9.4	+8.5	+10.7	+11.8	+11.4	+13.1	+11.6	+10.3
VI.	+9.8	+10.5	+9.0	+9.1	+10.1	+9.5	+9.0	+11.3	+12.3	+11.1	+10.9	+9.4	+10.2
VII.	+6.1	+7.3	+6.3	+8.9	+10.3	+9.2	+9.5	+10.9	+10.4	+6.8	+5.9	+5.3	+8.1
VIII.	+1.8	+2.6	+2.6	+3.5	+5.4	+6.2	+5.9	+5.5	+3.7	+1.4	+0.7	+1.0	+3.4
IX.	+2.0	+1.5	+1.1	+1.4	+0.4	+2.0	+0.3	+0.2	+1.4	+2.6	+3.3	+2.9	+1.5
X.	+5.3	+5.1	+4.7	+4.9	+4.3	+4.7	+3.0	+0.2	+5.7	+6.2	+6.7	+6.0	+5.1
XI.	+8.0	+8.3	+6.9	+8.1	+8.0	+8.1	+7.3	+8.7	+9.3	+9.1	+9.7	+9.1	+8.3
Noon.	+10.1	+10.1	+9.1	+10.3	+10.6	+10.6	+9.5	+10.9	+11.5	+10.0	+11.3	+10.8	+10.4
XIII.	+10.9	+11.4	+10.1	+11.6	+12.4	+12.2	+11.2	+13.1	+13.5	+12.0	+12.6	+12.1	+11.9
XIV.	+10.3	+12.1	+10.7	+11.4	+13.2	+13.2	+12.1	+14.1	+14.1	+12.5	+12.9	+11.4	+12.3
XV.	+9.3	+11.3	+10.1	+11.0	+13.2	+12.9	+12.2	+13.9	+14.1	+12.0	+12.6	+10.7	+11.9
XVI.	+8.3	+10.3	+9.4	+9.7	+11.8	+11.2	+10.5	+13.3	+12.8	+10.7	+11.3	+9.6	+10.7
XVII.	+6.7	+8.2	+7.5	+6.5	+7.5	+6.2	+6.5	+9.9	+9.9	+8.4	+8.5	+8.3	+7.8
XVIII.	+5.1	+4.9	+4.0	+2.5	+3.1	+2.1	+2.3	+4.2	+5.1	+4.1	+5.7	+5.3	+4.0
XIX.	+1.4	+1.3	+0.8	+0.2	+1.0	+0.0	+0.4	+0.9	+1.3	+1.1	+1.9	+1.4	+0.9
XX.	+1.1	+1.0	+1.1	+1.2	+0.5	+1.0	+1.2	+0.7	+0.8	+1.0	+1.0	+1.1	+1.0
XXI.	+3.1	+2.6	+2.7	+2.8	+2.6	+3.4	+2.4	+2.7	+3.2	+2.9	+3.4	+3.1	+2.9
XXII.	+4.3	+4.1	+3.7	+3.8	+3.6	+3.3	+3.6	+4.4	+4.8	+4.7	+4.8	+4.5	+4.2
XXIII.	+5.2	+5.0	+4.9	+4.9	+4.5	+4.2	+4.7	+5.5	+6.1	+5.8	+6.4	+5.9	+5.3
m.	+11.5	+11.4	+9.8	+10.0	+11.5	+11.6	+11.2	+13.2	+13.9	+13.3	+14.7	+12.9	+12.1
M.	+14.3	+14.8	+13.3	+13.4	+14.5	+13.4	+13.4	+15.5	+16.0	+14.5	+15.7	+15.0	+14.4
½(M+m).	+1.4	+1.7	+1.8	+1.7	+1.5	+0.9	+1.1	+1.1	+1.1	+0.6	+0.5	+1.1	+1.2
M-m.	+48.2	+47.7	+46.0	+39.8	+29.5	+25.7	+25.1	+25.9	+31.9	+38.2	+41.4	+46.8	+37.2

TABLE 10.—Corrections to be applied to the Hourly Temperatures of the Dew Point under Clear Skies in order to obtain the Mean.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
O.	-0.3	-0.2	-0.7	-0.2	+1.6	+1.8	+2.6	+2.4	+1.6	+0.7	+0.6	+1.3	°
I.	-0.2	-0.5	-0.6	-0.1	+1.5	+2.1	+2.6	+2.3	+1.1	+0.6	+0.7	+0.9	+0.9
II.	+0.1	-0.8	-0.4	+0.5	+1.9	+2.6	+3.1	+2.7	+1.8	+0.9	+0.6	+0.9	+0.8
III.	0.0	-1.2	-0.3	+0.9	+2.5	+3.2	+3.8	+3.1	+2.3	+1.6	+0.6	+0.7	+1.1
IV.	-0.4	-0.9	-0.3	+1.2	+2.5	+3.5	+4.3	+3.5	+2.9	+1.9	+0.8	+0.8	+1.4
V.	-0.7	-1.7	+0.1	+1.8	+2.6	+3.8	+4.7	+3.9	+3.4	+2.1	+1.1	+0.9	+1.8
VI.	-2.2	-2.4	+0.3	+2.1	+2.9	+4.1	+5.0	+4.0	+3.5	+1.5	-0.3	-1.5	+1.4
VII.	-3.3	-3.1	-0.8	+1.6	+2.1	+3.9	+4.6	+3.3	+1.3	-0.1	-1.6	-3.1	+0.4
VIII.	-2.9	-3.1	-1.7	-0.2	+0.4	+1.8	+2.2	+0.4	-0.6	-1.2	-2.2	-3.3	-0.9
IX.	-2.9	-3.3	-1.7	-1.1	-1.7	-0.8	-0.9	-1.6	-2.0	-1.9	-2.0	-3.3	-1.9
X.	-2.1	-2.8	-1.8	-0.7	-2.4	-2.1	-2.4	-2.7	-2.4	-1.8	-1.3	-2.8	-2.1
XI.	-1.1	-1.0	-1.0	-0.8	-3.1	-3.2	-3.5	-3.3	-2.4	-1.7	-1.1	-1.0	-1.9
Noon.	-0.1	+0.3	+0.3	-0.6	-2.6	-3.4	-4.0	-3.4	-2.7	-1.3	-1.0	-0.5	-1.6
XIII.	+0.6	+1.6	+1.3	0.0	-2.1	-3.1	4.0	-3.3	-2.2	-1.1	-0.5	-0.2	-1.1
XIV.	+1.3	+1.8	+1.8	0.0	-1.9	-3.4	4.1	-3.2	-2.3	-0.9	-0.3	+0.7	-0.9
XV.	+1.4	+2.4	+2.2	+0.3	-1.5	-2.9	-3.7	-2.9	-1.6	-0.5	+0.1	+1.2	-0.5
XVI.	+1.9	+3.0	+2.6	+0.4	-1.6	-3.0	-3.6	-2.6	-1.5	+0.1	+0.6	+1.7	-0.2
XVII.	+2.3	+3.0	+1.9	+0.3	-3.6	-4.7	-5.4	-3.9	-1.9	-0.1	+0.7	+1.9	-0.8
XVIII.	+2.5	+2.8	+0.7	-2.5	-2.0	-2.5	-3.3	-2.9	-2.3	-0.9	+0.7	+1.2	-0.7
XIX.	+1.1	+0.8	-1.2	-1.4	-0.5	-0.9	-1.8	-1.2	-0.9	-0.8	-0.4	+0.2	-0.6
XX.	+0.7	+0.8	-0.2	-0.6	+0.4	+0.3	-0.3	0.0	-0.1	+0.1	+0.3	-0.2	+0.1
XXI.	+1.1	+1.4	-0.1	0.0	+1.2	+1.0	+0.7	+1.0	+1.2	+0.7	+1.4	+0.9	+0.9
XXII.	+1.8	+1.3	0.0	+0.4	+1.8	+1.6	+1.2	+1.5	+1.6	+1.0	+1.7	+0.9	+1.2
XXIII.	+1.8	+1.4	0.0	+1.0	+2.2	+1.9	+1.9	+2.1	+1.9	+0.7	+2.0	+1.2	+1.2

TABLE II.—Corrections to be applied to the Hourly Temperatures of the Dew Point under Cloudy Skies in order to obtain the Mean.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
O.	°	°	°	°	°	°	°	°	°	°	°	°	°
I.	+0.2	+0.8	-0.4	+0.9	+1.6	+1.6	+1.6	+1.7	+1.9	+1.0	+1.6	-0.2	+1.0
II.	0.0	+0.4	-0.2	+1.0	+1.5	+1.9	+1.8	+1.6	+1.7	+0.9	+1.3	-0.4	+1.0
III.	-0.2	+0.2	0.0	+1.2	+1.7	+2.2	+1.7	+1.8	+1.6	+0.9	+1.2	-0.2	+1.0
IV.	-0.3	+0.3	+0.3	+1.4	+2.1	+2.5	+2.0	+2.0	+1.8	+1.0	+0.6	-0.3	+1.1
V.	-0.3	+0.4	+0.3	+1.3	+2.3	+2.6	+2.3	+2.5	+1.9	+1.0	+0.4	-0.5	+1.2
VI.	-1.0	+0.3	+0.4	+1.2	+2.4	+2.6	+2.7	+2.4	+2.1	+0.8	0.0	-0.9	+1.2
VII.	-1.7	-0.4	+0.5	+1.3	+2.2	+2.9	+3.0	+2.2	+2.0	-0.1	-1.4	-1.9	+0.8
VIII.	-1.1	-1.1	-0.7	+0.9	+1.7	+2.5	+2.6	+1.5	+0.4	-1.3	-2.3	-2.1	+0.1
IX.	-1.0	-1.2	-0.7	-0.9	0.0	+0.6	+0.9	-0.5	-0.8	-1.6	-2.6	-1.9	-0.8
X.	-0.5	-0.5	-0.5	-1.2	-1.5	-2.5	-1.9	-1.4	-1.6	-2.2	-2.5	-1.5	-1.4
XI.	+0.1	-0.1	-0.6	-0.9	-2.0	-2.7	-2.0	-2.2	-1.8	-1.7	-1.0	-0.2	-1.2
Noon.	+0.6	+0.3	-0.1	-0.4	-2.0	-2.7	-2.2	-2.1	-1.6	-1.1	-0.5	+0.2	-0.9
XIII.	+0.8	+0.7	+0.5	+0.2	-2.5	-2.6	-2.2	-2.2	-1.1	-0.8	0.0	+1.0	-0.6
XIV.	+1.1	+0.9	+1.0	-0.1	-1.0	-1.9	-2.1	-1.4	-1.2	-0.1	+0.2	+1.1	-0.3
XV.	+0.9	+1.2	+1.2	+0.5	-0.6	-1.9	-1.7	-0.9	-0.5	+0.5	+0.6	+1.6	+0.1
XVI.	+1.2	+1.8	+1.8	+0.1	-0.3	-2.0	-1.6	-0.8	-0.4	+0.8	+1.1	+2.0	+0.3
XVII.	+1.3	+1.2	+0.8	-2.0	-2.1	-3.0	-2.6	-1.5	-0.8	+0.6	+1.2	+2.0	-0.4
XVIII.	+0.9	+0.3	-0.3	-1.2	-1.8	-1.3	-1.5	-1.6	-1.0	+0.2	+1.0	+1.9	-0.3
XIX.	+0.1	-0.4	-0.6	-0.8	-0.9	-0.6	-0.5	-0.8	-0.6	0.0	+0.2	+0.9	-0.3
XX.	-0.3	-0.8	-0.7	-0.4	0.0	-0.1	-0.1	0.0	-0.1	+0.5	-0.1	+0.8	-0.1
XXI.	-0.6	-0.6	-0.5	-0.1	+0.1	0.0	+0.4	+0.6	+0.5	+0.9	+0.2	+0.5	+0.1
XXII.	-0.5	-0.5	-0.4	+0.3	+0.1	+0.6	+1.2	+0.6	+0.7	+1.0	+0.1	+0.3	+0.3
XXIII.	-0.3	-0.3	-0.7	+0.0	+1.1	+0.9	+1.1	+1.2	+1.0	+1.0	+0.3	+0.2	+0.5

TABLE 12.—Corrections to be applied to the Hourly Ratios of Humidity under Clear Skies in order to obtain the Mean.

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
O.	%	%	%	%	%	%	%	%	%	%	%	%	%
I.	-12.3	-11.5	-14.1	-12.7	-8.4	-8.9	-8.9	-8.4	-9.0	-10.5	-10.5	-8.8	-10.3
II.	-14.1	-14.9	-16.9	-15.5	-11.5	-11.0	-11.8	-11.7	-13.0	-13.5	-12.6	-12.5	-13.2
III.	-15.5	-18.3	-18.9	-17.2	-12.7	-13.2	-13.3	-13.1	-14.9	-15.3	-15.4	-14.4	-15.0
IV.	-16.8	-21.4	-21.6	-19.0	-13.8	-14.3	-13.9	-14.7	-16.5	-17.2	-18.3	-17.9	-17.0
V.	-20.5	-23.7	-23.9	-21.0	-16.3	-16.6	-14.6	-15.9	-17.8	-18.5	-21.3	-19.3	-19.0
VI.	-23.6	-26.2	-25.4	-22.6	-18.3	-17.3	-15.0	-17.0	-18.9	-20.0	-22.9	-22.3	-20.7
VII.	-25.5	-28.9	-27.0	-23.9	-20.0	-18.1	-15.4	-17.2	-20.8	-10.8	-20.3	-21.6	-21.6
VIII.	-16.7	-20.4	-24.2	-24.6	-23.1	-21.1	-18.5	-21.7	-19.5	-11.6	-10.4	-13.2	-18.7
IX.	-6.3	-7.8	-7.1	-9.5	-12.1	-12.5	-12.3	-9.6	-4.6	-2.0	-2.4	-4.8	-7.6
X.	0.2	0.4	+3.7	+3.7	+1.3	+1.4	0.0	+1.2	+2.5	+3.3	+3.3	+0.7	+1.7
XI.	+5.8	+6.2	+10.0	+13.1	+9.6	+0.4	+8.0	+7.8	+8.3	+8.1	+7.9	+6.0	+8.4
Noon.	+10.1	+12.4	+15.5	+18.1	+14.4	+15.4	+13.3	+12.8	+12.6	+11.1	+11.1	+11.0	+13.2
XIII.	+13.8	+16.1	+20.3	+21.6	+18.9	+19.1	+17.0	+16.2	+14.9	+14.5	+12.8	+13.5	+16.5
XIV.	+16.1	+19.4	+23.3	+24.6	+21.8	+23.0	+20.1	+18.6	+17.3	+15.4	+14.7	+15.6	+19.1
XV.	+17.9	+20.6	+24.9	+25.6	+23.1	+23.2	+21.5	+20.0	+18.3	+16.5	+16.1	+16.9	+20.4
XVI.	+18.7	+21.9	+26.0	+26.5	+23.6	+24.2	+22.5	+20.2	+19.2	+17.0	+16.7	+17.6	+21.3
XVII.	+19.1	+21.7	+26.0	+26.3	+22.4	+22.1	+21.2	+20.2	+18.6	+17.5	+16.7	+17.9	+20.8
XVIII.	+18.2	+20.7	+22.8	+17.1	+10.6	+7.9	+10.1	+13.9	+15.9	+15.4	+15.6	+17.1	+15.5
XIX.	+16.3	+18.1	+13.6	+4.2	+3.1	+1.9	+2.6	+5.2	+8.2	+9.5	+12.2	+13.8	+9.1
XX.	+9.5	+9.7	+4.0	+0.4	+0.8	0.3	+0.3	+2.5	+4.1	+4.2	+5.7	+7.5	+4.1
XXI.	+4.6	+4.9	+1.7	+0.9	-1.1	-1.1	-0.2	+0.7	+1.2	+2.3	+3.1	+3.2	+1.6
XXII.	+1.5	+2.4	-2.2	-3.3	-2.8	-2.6	-1.8	-0.8	-0.4	+0.4	+1.4	+1.8	-0.5
XXIII.	+0.5	-0.7	-4.9	-5.5	-4.4	-4.1	-4.9	-3.3	-2.4	-1.9	-0.8	-0.7	-2.7
	-2.0	-2.3	-7.5	-6.5	-5.5	-5.8	-6.2	-4.5	-4.0	-5.2	-2.5	-2.8	-4.5

TABLE 13.—Corrections to be applied to the Hourly Ratios of Humidity under Cloudy Skies in order to obtain the Mean.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	%	%	%	%	%	%	%	%	%	%	%	%	%
O.	+8.4	+7.8	+11.7	+9.2	+8.0	+5.8	+7.4	+6.6	+8.0	+8.6	+6.8	+10.3	+8.2
I.	+9.0	+10.4	+13.1	+11.3	+10.9	+7.6	+8.8	+10.2	+10.5	+11.0	+9.6	+12.5	+10.1
II.	+12.6	+13.2	+15.1	+12.4	+12.2	+9.5	+10.1	+12.5	+11.6	+12.8	+12.3	+14.4	+12.4
III.	+15.2	+14.2	+16.2	+13.9	+13.2	+11.0	+11.5	+13.4	+13.7	+15.0	+15.0	+16.1	+14.0
IV.	+16.3	+15.6	+16.9	+15.9	+14.2	+13.0	+12.6	+14.5	+15.3	+17.2	+18.0	+19.3	+15.7
V.	+18.5	+17.1	+17.7	+17.1	+15.5	+14.4	+13.8	+16.2	+16.8	+19.3	+20.2	+21.2	+17.3
VI.	+19.1	+19.7	+18.9	+18.4	+17.5	+15.7	+15.2	+18.3	+18.3	+20.1	+18.8	+18.4	+18.1
VII.	+12.0	+13.8	+16.2	+19.2	+19.9	+17.0	+17.3	+18.8	+17.0	+12.6	+10.2	+9.9	+15.3
VIII.	+2.1	+4.7	+5.4	+7.9	+11.3	+11.8	+10.6	+10.0	+6.2	+2.7	+2.4	+1.9	+0.4
IX.	+3.8	+2.5	+3.1	+2.2	+0.1	+1.5	+1.1	+0.4	+1.2	+2.9	+3.1	+4.2	+1.7
X.	+10.0	+9.1	+9.7	+9.4	+6.0	+6.2	+5.7	+6.0	+6.7	+8.5	+8.4	+9.2	+8.0
XI.	+14.5	+13.6	+14.7	+15.6	+12.6	+12.2	+11.7	+11.2	+12.0	+12.5	+12.6	+14.0	+13.1
Noon.	+17.5	+16.3	+18.5	+20.1	+17.1	+16.2	+16.2	+14.9	+15.4	+14.6	+14.6	+16.3	+16.5
XIII.	+18.3	+18.4	+20.2	+23.3	+19.8	+18.6	+18.8	+18.2	+18.0	+16.7	+16.2	+18.1	+18.8
XIV.	+17.4	+18.9	+22.1	+21.9	+21.5	+20.3	+19.9	+19.8	+18.8	+17.9	+16.1	+16.9	+19.2
XV.	+15.6	+18.0	+21.2	+21.2	+22.7	+20.3	+20.4	+20.4	+18.7	+17.8	+16.0	+16.2	+19.1
XVI.	+14.6	+17.7	+20.9	+18.5	+20.6	+18.0	+18.4	+19.3	+17.8	+16.2	+15.3	+14.9	+17.7
XVII.	+12.7	+13.9	+16.6	+11.7	+11.4	+7.9	+9.0	+14.8	+14.0	+13.5	+12.2	+13.7	+12.6
XVIII.	+9.8	+8.2	+9.8	+4.0	+3.9	+3.1	+2.6	+6.3	+7.7	+7.9	+9.3	+10.5	+7.0
XIX.	+3.2	+2.1	+2.3	+0.1	+1.4	+0.2	+0.5	+2.1	+2.8	+2.9	+4.0	+3.9	+2.1
XX.	+1.0	+2.1	+2.0	+2.7	+0.3	+0.6	+1.8	+0.9	+0.1	+0.4	+0.2	+0.3	+0.7
XXI.	+5.4	+4.6	+5.2	+5.8	+3.7	+3.1	+3.4	+1.9	+3.0	+2.0	+2.6	+3.3	+3.6
XXII.	+7.0	+6.8	+7.9	+7.1	+5.3	+4.1	+5.3	+5.1	+5.1	+4.8	+5.0	+5.5	+5.7
XXIII.	+8.9	+8.0	+11.2	+9.0	+6.2	+5.8	+7.3	+6.5	+7.2	+6.5	+7.2	+8.3	+7.6

TABLE 14.—Harmonic Constants.

	Annual Normals.					Annual Normals for Clear Skies.				Annual Normals for Cloudy Skies.			
	Pressure.	Temperature.	Dew Point.	Humidity.		Pressure.	Temperature.	Dew Point.	Humidity.	Pressure.	Temperature.	Dew Point.	Humidity.
	inch.		°	%		inch.		°	%	inch.	°	°	%
U <sub>1</sub>	.0276	12.247	1.223	18.128		.0285	14.121	1.610	18.741	.0272	10.802	.869	17.499
U <sub>2</sub>	.0245	3.068	.554	4.870		.0231	3.332	.626	5.135	.0250	2.726	.559	4.882
U <sub>3</sub>	.0017	.741	.439	1.180		.0013	1.106	.560	1.570	.0015	.642	.318	1.234
U <sub>4</sub>	.0002	.803	.068	1.569		.0001	1.015	.127	1.850	.0003	.619	.098	1.136
	"	"	"	"		"	"	"	"	"	"	"	"
V <sub>1</sub>	357.5	231.0	251.2	47.5		348.8	229.6	246.7	46.0	2.3	232.3	263.9	48.5
V <sub>2</sub>	158.7	61.8	158.9	249.9		158.1	59.2	156.8	253.2	159.2	63.9	163.7	246.6
V <sub>3</sub>	357.1	23.9	6.2	107.2		353.8	35.1	5.2	207.0	4.6	20.4	2.7	195.2
V <sub>4</sub>	330.0	226.2	342.1	44.1		270.0	225.3	333.7	52.3	43.9	228.4	342.9	43.6

TABLE 15.—Kämtz Factors.

	Kenilworth.			Northern Hemi- sphere.
	Clear Days.	Cloudy Days.	All Days.	
Jan.	·507	·446	·464	·507
Feb.	·487	·435	·451	·476
Mar.	·475	·424	·440	·475
April	·463	·426	·441	·466
May	·448	·442	·446	·459
June	·438	·464	·440	·453
July	·443	·455	·447	·462
Aug.	·407	·460	·404	·451
Sept.	·486	·465	·472	·433
Oct.	·500	·478	·488	·447
Nov.	·516	·483	·497	·496
Dec.	·515	·462	·480	·521
Year	·511	·455	·462	...

## II.—ON THE ELECTRIFICATION OF THE ATMOSPHERE SURROUNDING SOLID BODIES WHEN THESE ARE RAISED TO MODERATE TEMPERATURES.

By J. C. BEATTIE, D.Sc., F.R.S.E.

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§1. The effect of increase of temperature of the charged body on its capability of retaining a charge has been made the subject of research by numerous experimenters.

Guthrie showed that a metal—in his experiments an iron sphere—when white hot cannot retain a charge either of positive or of negative electricity; and that as it cools it acquires the power of retaining a negative charge before it can retain a positive one.

Elster and Geitel have shown that a conductor insulated in the neighbourhood of a glowing body becomes charged in air which previously had been rendered free from dust particles. These experimenters have also shown that a body made to glow in a gaseous atmosphere takes a charge whose value depends on the nature and *state* of glow of the body as well as on the nature and density of the surrounding gas.

Schuster states that a glowing copper rod gives off negative electricity to the air so long as it is oxidising. After the oxidation is complete it retains a charge given it, whether the charge be positive or negative. On the other hand, when an oxidised copper wire was made to glow in hydrogen, it retained a negative but not a positive charge so long as there was deoxidation, and even for a time after the deoxidation had ceased.

Branly states that the electrification of the air surrounding a glowing surface depends on the nature of the surface. He found, for an example, that a red-hot glass rod, when connected to the ground, discharges negative electricity, while a lamp cylinder covered with aluminium oxide, bismuth oxide, or lead oxide, discharges positive electricity.

J. J. Thomson has observed that a charged metallic body surrounded by a heated atmosphere has greater power of communicating a charge to the atmosphere when it is hot than it has when cold.

Closely connected with the various phenomena mentioned above is the well-known discharging power of flames with or without volatilized substances in them.

Of recent years it has been possible—thanks to Kelvin's electric filter method—to examine not only the change in the electric state of the solid, but also the change in that of the surrounding gas.

In the present paper a number of experimental results are given relating to the electrification of gases surrounding metallic bodies when these bodies and their surrounding atmospheres are heated to a temperature below that of the melting point of zinc. The paper is complementary to two published in the "Philosophical Magazine,"\* where, however, the electric state of the solid was considered.

## §2. Experimental Arrangement.

To test the electric condition of the gases two arrangements were used.

In the first of these, Fig. IV., a metal tube (A), usually of 5 cm. internal diameter of 1.6 to 3.2 mm. in thickness, and of 82 cm. in length, was used. Each end was closed with a tightly-fitting, asbestos-covered cork, through the centre of which was passed a wire or metal strip (M), so that it lay approximately in the axis of the tube. This will be referred to as the axial wire. In addition, each cork had a glass tube passing through it, the one in the cork at the ingress end could be joined by rubber tubing to a glass wool filter (F<sub>1</sub>), and a Woulff's bottle (W), containing water or strong sulphuric acid as the case might be; the filter was always joined metallically to the tube (A).

To the glass tube at the egress end of (A) was joined a rubber tube, which in turn led, through a Woulff bottle (W<sub>2</sub>), to a glass tube fitting into one end of a tunnel in a piece of paraffin. Another glass-wool filter (F<sub>2</sub>) was fixed on to the other end of the tunnel in the same piece of paraffin, and to a second tunnelled piece. In the other end of this second piece was fixed another glass tube, from which a piece of rubber tube led to the air pump. The tube (A) could be placed in a tube-heating furnace of the ordinary pattern. In some experiments the tube (A) was exposed directly to the flame; in others it was covered with asbestos and wire gauze.

In the second arrangement, tube (A) was replaced by two cylindrical vessels of iron, Fig. V., about 15 cm. in diameter, the lower 30 cm., the upper 10 cm. in height. The upper telescoped into the lower, and thus formed an hermetically-sealed lid. At a height of 3.8 cm. from the bottom of the lower and diametrically opposite to each other were fixed two iron tubes (A) and (B), each about 45 cm. long and 1.2 cm. internal diameter. Through the middle of the lid was passed a stout brass wire (W), surrounded and insulated from the lid by ebonite wrapped in asbestos, great care being taken to make the fitting air-tight. The end (E) of the brass wire carried a thin disc of zinc, 10 cm. in diameter. A second disc of zinc was laid on the inside of the bottom of the lower vessel. The tubes (A) and (B) were closed at the ends remote from the cylinders by tightly-fitting corks, each supplied with a glass tube leading by rubber tubing to various filters and wash-bottles as in the first arrangement. Asbestos was placed on the sides and on the

\* "Phil. Mag." ser. 5, vol. XLVIII., pp. 97-106 (July 1899);

"Phil. Mag.," ser. 6, vol. 1., pp. 442-454 (April 1901).

base of the iron cylinder and on the ends of the pipes (A) and (B) next the cylinder. The flame was placed underneath the base of the cylinder.

A quadrant electrometer, surrounded by wire gauze, was used in both arrangements. The filter ( $F_1$ ) was inside the gauze and in permanent metallic connection with one pair of quadrants. This pair could be joined to case or insulated at will. The metal tubes and cylinders, the filter ( $F_2$ ), the wire gauze and the other pair of quadrants were metallically connected with the case of the instrument. The axial wire in the first arrangement, or the stout brass wire in the second, could be connected with the case of the instrument or with the source of a constant E.M.F. just as desired. It may be stated once for all, that, before each experiment, the electrometer, with connected filter ( $F_1$ ), was tested for insulation, and no results were taken when the insulation was faulty. Tests were always made to ascertain that the air passed from the room through the filter ( $F_1$ ), through the metallic vessels, through the filter ( $F_2$ ), and thence to the pump. In no case was any trace of electrification obtained on drawing air from the room in this way when the flame was not lit. Great care was also taken to prevent products of combustion from entering the metallic vessels.

§3. Preliminary Experiments with an iron tube, a copper tube, and with phosphorus in a zinc tube, the arrangement being as in Fig. IV.

In the case of the iron and the copper tubes, six burners in the furnace were used, and the flame was applied directly. The tubes were heated to a cherry red. In the case of the iron tube, it was found that, with everything to case, the air drawn through was positively electrified when tested by the filter ( $F_2$ ). The amount of the electrification increased with the electromotive force. The nature of it was positive, quite irrespective of the nature of the charge given to the insulated axial wire. The electrification was not removed by drawing the air through (i.) a U-tube filled with pumice-stone soaked in strong sulphuric acid, (ii.) a wash-bottle containing water, (iii.) first water and then a solution of potassium iodide in water, or (iv.) an alkaline solution of pyrogalllic acid and a U-tube containing pumice-stone soaked in strong sulphuric acid. It was removed so far as the filter ( $F_2$ ) was able to test by drawing the air through water, potassium iodide solution, pyrogalllic acid and the U-tube, before reaching the filter.

It is to be remembered, however, that the effect of passing the electrified air through solutions of this nature is twofold, (a) certain constituents may be taken from the air, or (b) the bubbling may cause an electrification of the air sufficient to give an indication on the filter. This latter effect was allowed for by drawing non-electrified air through the various solutions, and then testing by the filter. The result was a slight negative electrification, causing a deviation of a fraction of a scale division on the electrometer.

The following table shows the effects produced.

The figures are the mean of a number of experiments.

Electrified Air from Iron Tube was drawn through.	Deviation of Electro-meter in volts per Stroke of Pump.
I. R. Tube only	+0.070
(i.) I. R. Tube + U tube with Pumice and $H_2SO_4$	+0.060
(ii.) I. R. Tube + water	+0.050
(iii.) I. R. Tube + water + KI solution	+0.045
(iv.) I. R. Tube + 'Pyro' + U. tube	+0.016
(v.) I. R. Tube + water + KI + Pyro	+0.020
(vi.) I. R. Tube + water + KI + Pyro + U Tube	+0.000

From this we might infer that the electrification is not carried to any extent by solid particles, by water vapour, or by ozone, but it would seem to be carried by the oxygen chiefly.

In the case of the copper tube at a red heat, the effect produced, as the air was passed through, was a positive electrification of the air. After the tube was oxidized coal gas was passed through, which when tested by the filter showed a large negative electrification. The positive and the negative electrifications were observed even with the whole apparatus to case, a change in the sign of the electrification of the copper tube relative to the insulated axial wire did not produce a change in the electrification of the air or of the coal gas.

In the experiments with phosphorus, a clean stick of that element about six inches long was placed in a small zinc trough. Water was then poured into the trough so as to leave exposed only the upper side of the stick of phosphorus. The zinc vessel was then placed inside a zinc tube. When the whole was connected to case and air was drawn off to the filter—precautions being taken to ensure that the air drawn to the filter passed first over the phosphorus—it was found that little or no electrification was shown on the filter. On the other hand, when the zinc tube with which the zinc vessel containing the phosphorus was in metallic contact was connected to one terminal of a battery of Leclanché cells and to the case of the instrument, while the insulated axial wire was connected to the other terminal of the battery, the air was found to be positively or negatively electrified according as the insulated wire was negatively or positively electrified. The electrification due to the oxidation of phosphorus shows in this respect a marked difference from that due to oxidation caused by heating.

The fact that clean iron and clean copper, when oxidizing, electrify the surrounding air positively was experimentally verified by Schuster. The effect due to phosphorus has been studied very thoroughly by Elster and Geitel. These known results are given here simply to indicate the capability of the present arrangement wherein an electric filter is used.

#### §4. Electrification of gases at temperatures below $400^{\circ}\text{C}$ .

In the experiments now to be described, the outstanding difference is the temperature at which the results are produced.

No attempt was made to determine the temperature accurately. The highest temperature attained was about  $350^{\circ}\text{C}$ , the melting point of zinc. The effect of heating to a temperature slightly lower than this was tried with a great many substances and combinations of substances.

The substances may be divided into two classes: (1) those which, when heated, in certain circumstances, acquire the power of giving a charge to the surrounding air; (2) those which, in like circumstances, do not acquire this power. The first class may be sub-divided into (a) those in which it was possible to predict what would happen, and (b) those in which it was not possible to predict.

In class (b) is potassium permanganate. This substance was tried several times with the first experimental arrangement. There was always evidence that a gas was being given off in the back pressure in the wash-bottles. When the air from the room was drawn through while the tube was being heated, it was found that the charge given to the filter ( $F_0$ ) was sometimes positive and sometimes negative. Usually it was possible in the early part of the experiment to influence the charge given to the filter by giving a charge of a definite kind to the insulated axial wire; for example, in one experiment with the wire joined to the negative terminal of a battery of 40 Leclanché's, the electrification given to the filter was positive, to the positive terminal it was negative. As the temperature rose, the positive reading became less and less, till, finally, in all cases, the electrification given to the filter ( $F_0$ ) was negative.

A second substance behaving in a very erratic manner was zinc chloride. Some days the results were negative, on others positive. Consistent results were obtained with potassium bichromate, treated with iodine or with bromine, on a zinc strip placed in a zinc tube; with common salt similarly treated, with lithium chloride under like conditions, with potassium iodide treated with bromine, and with zinc sulphide alone. No electrification of the atmosphere was obtained in the case of potassium bichromate, common salt, lithium chloride, treated with iodine or with bromine, in the absence of zinc. The effect of the absence of zinc in the case of potassium iodide treated with bromine was not tried. Zinc sulphide was not tried in the absence of zinc.

The substances of the second class, *i.e.*, those which, when heated, showed no electrification of the surrounding atmosphere, were barium sulphide, either alone or after being treated with iodine and heated in an iron tube, barium oxide and barium peroxide heated in an iron tube, copper oxide heated in an iron tube, copper sulphide similarly heated, potassium carbonate with or without iodine in a zinc tube, potassium bicarbonate in a zinc tube, potassium nitrate in a zinc tube, strontium nitrate in a zinc tube, common salt with iodine or bromine in an aluminium tube.

## §5. Questions for experimental investigation.

Experiments were made to test (a) whether the nature of the electrification, positive or negative, given to the air could be determined by the nature of the charge given to the surrounding vessel i.e. how the electrification of the gas was influenced by the electromotive force; (b) what it was that carried the electrification; (c) whether the electrification of the gas was destroyed by passing a current through it, when electrified; (d) whether it was possible to transmit the agency effective in causing the electrification from one space to another by means of drawing the electrified air from one space to another.

## §6. The effect of the electromotive force on the electrification of the gas.

In the various experiments the zinc alone was first tested, the temperature being such as to cause oxidation but not fusion of the zinc. It was found that in such circumstances the air was not electrified. Potassium bichromate was first placed on a strip of zinc, 22.5 cm. by 2 cm., and sprinkled with iodine, and in some cases the whole was placed in the zinc tube, but in later experiments the zinc strip and its covering of potassium bichromate and iodine were heated so as to drive off the iodine, and then the strip was placed in the zinc tube and heated. In cases where bromine was used the bromine was sprinkled over the potassium bichromate on the zinc strip, and allowed to evaporate, and then the whole was placed in the zinc tube and heated. The air drawn through the tube and tested by the filter ( $F_2$ ) was strongly electrified positively even with everything to case. The electrification was positive both when the insulated axial wire was joined to the positive and when it was joined to the negative terminal of the Leclanché battery, the other terminal being joined to the zinc tube and the case of the instrument. The results are exhibited in the following tables:—

POTASSIUM BICHROMATE AND BROMINE ON A ZINC  
STRIP IN ZINC TUBE.

Axial Wire.	Deviation in Volts per Stroke of Pump.
Case	+0.054
+ 3 volts	+0.050
+12 volts	+0.063
+36 volts	+0.075

**POTASSIUM BICHROMATE WITH IODINE ON A  
ZINC STRIP IN ZINC TUBE.**

Axial Wire.	Deviation in Volts per Stroke of Pump.
Case	+0.063
+ 1.5 volts	+0.067
+ 3.0 "	+0.080
+ 6.0 "	+0.075
+ 12.0 "	+0.067
+ 36.0 "	+0.059
— 1.5 "	+0.084
— 3.0 "	+0.088
— 6.0 "	+0.084
— 12.0 "	+0.084
— 36.0 "	+0.059

Iodined salt on zinc and the substances enumerated in class (ii.) (b) behaved in a similar way. The electrification in all these cases at a temperature just below the melting point of zinc was positive, and practically independent of the drop of voltage between the insulated axial wire and the metal tube with all the voltages used in the experiments.

These substances were also tried with the second experimental arrangement. The distance between the insulated disc and the substance on the disinsulated zinc disc on the bottom of the vessel was varied from two to eleven centimetres with changing the sign of the electrification. It was found that the sign of the electrification given to the filter ( $F_c$ ) changed to negative when the temperature was such as to fuse the zinc.

§7. The carrier of the electric charge.

In the first experimental arrangement, Fig. IV., Woulff's bottles could be placed between the tube and the filter ( $F_c$ ). The air was drawn through these wash-bottles singly or in various groups. These wash-bottles were insulated. The following table gives the results obtained in one experiment in which potassium bichromate sprinkled with iodine was placed on zinc. The axial wire was connected to case.

Deviation in Volts per Stroke of Pump.	Air drawn through.
+0.038	(1) Water (2) KI solution (3) U-tube with Pumice and $H_2SO_4$
+0.042	(2) and (3) as above.
+0.046	(2) as above.
+0.042	Nothing.

Many experiments were made. The above gives a fair idea of the result. Another solution often employed was an alkaline solution of pyrogallic acid. The effect of this was to reduce the reading slightly when salt and iodine, or lithium chloride and iodine were used.

The effect was much more marked when (1) potassium iodide and bromine or (2) zinc chloride was used. The following table will give an idea of the results obtained when these substances were used.

POTASSIUM IODIDE ON WHICH BROMINE HAD BEEN  
SPRINKLED ON A ZINC STRIP IN A ZINC TUBE.

Axial Wire.	Deviation in Volts per Stroke of Pump.	Air drawn through.
Case	+0.26	(1) Strong $H_2SO_4$
+60 volts	+1.55	(1) As above
-60 "	+2.17	(1) As above
-60 "	+0.38	(1) and (2) Pyro
-60 "	+1.20	(1) As above
-60 "	+0.53	(2) As above
-60 "	+0.30	(1) As above
-60 "	+1.75	Nothing
-60 "	+0.50	(1) As above

Here there is a decided change when the "pyro" and  $H_2SO_4$  are used as traps. Quite as decided an effect was produced with zinc chloride in a zinc tube.

The experiments were varied by drawing different gases through the tube. The following table gives the results obtained with

COMMON SALT AND IODINE ON A ZINC STRIP IN A  
ZINC TUBE :—

Axial Wire.	Deviation in Volts per Stroke.	Gas.	Date.
To Case.	+0.36	Air	15th June, 1901
"	+0.36	Nitrogen	" "
"	+0.16	Air	18th "
"	+0.004	Hydrogen	" "
"	+0.14	Air	" "
"	+0.18	Coal Gas	" "

Results with oxygen or carbonic acid gas were not noticeably different from those in air.

§8. Possibility of transmitting the effect from one place to another.

To test whether it was possible to transmit the agency effective in causing the electrification from one space to another, the first arrangement was modified by introducing between the tube (A) and the filter ( $F_e$ ), a second tube ( $A_1$ ), similar in all respects to A.

(A) was heated; ( $A_1$ ) was in the first part of the experiment connected to case, and in it was placed a strip of zinc covered with common salt, which had not, however, been treated with iodine. The electrified air from (A), in which was a strip of zinc covered with iodined salt, was allowed to pass through ( $A_1$ ) before reaching the filter ( $F_e$ ). After this had been continued for some time (A) was taken away and ( $A_1$ ) was heated. No electrification was shown on the filter when the air was drawn through it from the tube ( $A_1$ ).

#### §9. Effect of current.

The charge given to the gas was not destroyed by passing a current through it. This was tested by an arrangement similar to that described in §8. The gas was charged in (A); it was drawn through ( $A_1$ ) which contained no substance; the insulated axial wire of (A) was connected to one terminal and the tube itself to the other terminal of a battery of forty Leclanché's. No diminution of the effect on the filter was produced by this means.

§10. Quantity of electricity given in filter ( $F_e$ ) by a c.cm. of gas.

The capacity of the quadrant electrometer with connected filter was '0001 microfarads. The capacity of a barrel of the pump was 344 cubic centimetres. The quantity of electricity per cm.<sup>3</sup> was as follows:—

	Axial Wire.	Conlombs per cm. <sup>3</sup>
Air from Iron Tube ... ..	+220	+ 9.0 × 10 <sup>-7</sup>
Coal Gas from Copper Tube... ..	+36 volts -36 "	- 4.5 × 10 <sup>-7</sup> -10.0 × 10 <sup>-7</sup>
Air from Phosphorus Tube ... ..	+36 " -36 "	- 1.4 × 10 <sup>-7</sup> + 1.1 × 10 <sup>-7</sup>
" Zinc Tube with Iodined Salt ...	+36 " -36 "	+ 1.2 × 10 <sup>-7</sup> + 0.8 × 10 <sup>-7</sup>
" " " Potassium Permanganate	+60 " -60 "	- 2.8 × 10 <sup>-7</sup> + 2.2 × 10 <sup>-7</sup>
" " " Lithium Chloride	+45 "	+ 6.6 × 10 <sup>-7</sup>
" " " Potassium Iodide and Bromine	+60 " -60 "	+ 4.0 × 10 <sup>-7</sup> + 6.0 × 10 <sup>-7</sup>

## §11. Conclusions.

1. The following substances, common salt, lithium chloride, potassium bichromate, on which iodine or bromine has been sprinkled, have, in the presence of zinc, the property of causing the surrounding atmosphere of air, oxygen, nitrogen, carbonic acid or coal gas to become electrified positively when raised to a temperature between  $300^{\circ}\text{C}$ . and  $350^{\circ}\text{C}$ . An atmosphere of hydrogen is not electrified in similar circumstances. Stress is to be laid on the fact that it is the atmosphere, not the solid particles, nor the ozone, nor the water vapour which takes the electrification. The electrification is not due to a gas coming off as it is in the case of potassium permanganate.

2. The effect differs from the electrification produced by phosphorus, röntgen rays, uranium, or thorium in that it is only possible to electrify the gas positively with voltages up to +200 volts.

3. The effect differs from that produced in a red hot iron or copper tube in that it does not appear to be due to oxidation or deoxidation.

4. The atmosphere under the action of these substances brings about an equalization of potential between two mutually insulated different metals; in other words, when the two mutually insulated metals are connected by a wire the circuit is completed by the intervening atmosphere, and a current flows.

5. Other substances which have this property are potassium iodide, treated with bromine, in the presence of zinc, zinc sulphide, zinc chloride, and a number of substances mentioned in §4.

6. The effect does not seem to be connected with fluorescence, thermoluminescence, or with the giving off of a gas on heating.

7. There seems to be three distinct methods—apart altogether from the well-known electrifying properties of flames and their fumes—of obtaining an electrified gas by heating.

1. By oxidation or by deoxidation as in the atmosphere drawn from the neighbourhood of an oxidising or deoxidising metal. (Schuster.)
2. By driving off from a solid a gas which carries a charge with it as in the gas obtained by heating potassium permanganate. (Townsend.)
3. By heating the atmosphere over iodined common salt—and other iodined or bromined substances mentioned above—in the presence of zinc; or by heating the atmosphere in the presence of a number of substances, such as zinc chloride, zinc sulphide.

## 12.—A THIRD LIST OF WRITINGS ON DETERMINANTS.

By THOMAS MUIR, LL.D., F.R.S.

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1. The first "List of Writings on Determinants" was published in the *Quarterly Journal of Mathematics*, Vol. XVIII., pp. 110-149. It covered the period 1693-1880, and contained 589 titles of books, memoirs, etc., which had appeared within that period. In the preparation of it the primary object aimed at was to provide working mathematicians with the means of knowing what had been done by their predecessors, and so to make research less laborious and at the same time more fruitful. It was also intended that the material thus collected should be immediately used by myself in the writing of an exhaustive history of the theory; and in part this intention was carried out in the years 1884-89, the first volume of the work having been published in 1890.

The second list appeared in the same journal, Vol. XXI., pp. 299-320, and covered the period 1784-1885, thus supplying omitted titles, 84 in number, belonging to the period of the first list, and giving the titles, 176 in number, for an additional period of five years.

2. The present list is similar to the second, but is much more extensive, the new period dealt with being three times as long. It opens with the supply of omissions made in the previous lists, and contains in all more titles than these two lists put together.

In view of the repeated gleanings thus seen to have been made, and in view of the fact that the literature of quite recent times can be examined easily and with little chance of making omissions or mistakes, it is highly probable that the 1744 titles which the three lists together contain form a practically complete conspectus of all the work that has been done on the subject from the earliest times up to the close of the nineteenth century. The existence of the *International Scientific Catalogue* and other publications of a more special character makes the twentieth century a matter of comparatively little concern to the collector of historical material.

3. As in the case of the previous lists, the writings meant to be included are those which concern the *theory* or the *history of the theory*; all papers which contain mere instances of the *application* of the functions are carefully omitted. At the same time, if a paper, while professing to deal with a mere application of determinants, or even to concern a totally different subject, should, nevertheless, throw some sidelight on the theory, it has been as scrupulously noted as if its title bore reference to the theory, and to the theory only.

4. The order of arrangement of the titles is meant to be the order of their dates, and this not merely so far as the year is concerned, but the month as well. It has to be noted, however, that such accuracy is far from being completely attainable, and will never be attainable until there is some general agreement made and acted upon as to the mode of dating scientific writings in all the different mediums of publication.

In the domain of mathematics these mediums are practically not more than four in number, viz.: (1) The serial publications of societies; (2) publications of the magazine class; (3) books and pamphlets separately published; (4) school-programms and university-dissertations. In regard to the first of these it would seem desirable that every printed paper should bear the date of its receipt by the secretary of the society, or the date of its presentation to the society, or both dates; and, further, that the fasciculus of the society's publication which contains the paper should bear the date of its issue to the public. Some of the leading societies already comply with all these requirements; most societies comply in part; but, strange to say, there are still laggards whose publications have only a year-date on the title-page of each volume—a year-date which very probably is not appropriate to even a minority of the papers which the volume contains.

In the case of magazines, journals, etc., there is still more variety and more carelessness than in the case of the serials of societies. The best editors print at the end of each paper the date placed there by the author, and in addition print on the cover of each fasciculus the date of its issue. Such editors, however, are few in number; and, unfortunately, some of those in England are among the worst, the author's date being almost invariably wanting, and the month mentioned on the cover being often quite misleading.

Books and pamphlets sometimes bear two dates, the day-date at the end of the preface and the year-date on the title-page; the date of actual issue to the public is almost never ascertainable from the book itself, and exceedingly difficult to obtain otherwise.

Degree-dissertations and the papers contained in school-programms usually bear the date of the occasion on which they were held up to honour, and, like other separate publications, bear a year-date on the title-page. They show no exact date of publication, and there is the further difficulty that they are not catalogued in the ordinary dated bibliographies issued for the information of book-sellers.

5. In the great majority of cases the language of the printed title given in the following list is the language in which the paper originally appeared. When a different course is taken an English translation of the title is given, and for distinction's sake is enclosed in brackets. The languages which have been thus treated are Russian, Polish, Hungarian, Czech, and others less commonly known. When there is no title in the original, an English title descriptive of the contents is given and enclosed in the same way.

In some cases the names of the serials are similarly dealt with.

6. There is no single library in existence which contains all the writings included in the three lists, or even in the last of the three; and, what is still more to be regretted, there is apparently no single library in the United Kingdom which contains full sets of all the societies' serials referred to, none which contains full sets of all the mathematical magazines, none which contains all the separate books and pamphlets, and none which contains all the degree-dissertations and school-programms. The English mathematical societies, to whose libraries one naturally turns for full sets of the purely mathematical serials, leave their members in ignorance as to what they possess of this kind. They publish, it is true, in irregular instalments the names of the serials which they receive in exchange for their Proceedings, but nowhere any complete list of all the serials which are accessible in their rooms. Still less effort do they make to inform their members of the whereabouts of libraries where sets of serials are kept which they themselves do not possess. The current mathematical serials of the world are not above eighty in number; they, therefore, could be catalogued on two pages of either society's Proceedings, and by doubling the space it would be possible to indicate fully not only the volumes actually possessed by the society, but also possessed by any important libraries within the same city. In the case of the Edinburgh Mathematical Society, the catalogue might easily and with advantage include all the larger libraries of Scotland within its purview; and in the case of the London Mathematical Society certain libraries at Cambridge and Oxford could not well be omitted. The printing of such four-page catalogues would at least make evident to members "the nakedness of the land," and might stir them up to make an effort to supply the more important wants.\*

8. To increase the usefulness of the three lists, and, so to speak, complete the work connected with them, there has been appended to the present list an index of all the authors' names appearing in any one of the three. This is arranged alphabetically, and the lists having been designated (A), (B), (C) in order, each paper is fully indicated by giving one of these letters to show the list to which the paper belongs, and printing after it the year-date of the paper. Thus the entry

NOETHER, M.            A 1876, 79(2): C 95.

intimates that the author in question has a paper under the year 1876 in the first list, two papers under the year 1879 in the same list, and a paper under the year 1895 in the third list.

\*The new University of London has a splendid heritage in the Graves Library of University College. Present and future graduates could do a noble work by keeping all the sets of serials in the library up-to-date and in other ways maintaining its original high character for completeness.

9. It will readily be understood that the preparation of the list has involved much labour to others beside myself, and that a considerable share of this is due to the fact of my distance from the great libraries of Europe. About one hundred and eighty of the title-slips cost more worry to check and complete than all the rest put together, and some of them made the journey to and from Europe several times before they could be filed as satisfactory.† In recalling this it gives me pleasure to say that in almost no case did I apply to strangers for assistance without receiving at least a sympathetic answer. Such kindnesses I have already tried to acknowledge in some way or other; but to most of those who rendered them the appearance of the list in print will, I feel sure, be the best form of reward.

## THE THIRD LIST (1748-1900).

1748. FONTAINE [DES BERTINS, A.] Mémoires données à l'Académie des Sciences, non imprimés dans leur temps. (p. 94.) 588 pp. Paris. 1764.
1770. VANDERMONDE. Mémoire sur la résolution des équations. *Mém. de l'Acad. des Sciences, Année 1771.* p. 369.
1773. LAGRANGE, J. L. Recherches d'arithmétique. *Nouv. Mém. de l'Acad. Roy. .... Berlin, Ann. 1773.* (pp. 265-312.) p. 285.
1795. PRONY [R.]. Leçons d'analyse. Considérations sur les principes de la méthode inverse des différences. *Journ. de l'Ecole Polyt.* I. (pp. 211-273.) pp. 264, 265.
1809. MONGE [G.]. Essai d'application de l'analyse à quelques parties de la géométrie élémentaire. *Journ. de l'Ecole Polyt.* VIII., pp. 107-109.
1809. HIRSCH, M. Sammlung von Aufgaben aus der Theorie der algebraischen Gleichungen. pp. 103-107. Berlin.
1811. PRASSE, M. DE. Commentationes Mathematicae. vii. Demonstratio eliminationis Cramerianae. pp. 89-102. Lipsiae. 1804-1812.
1811. BINET, J. P. M. Mémoire sur la théorie des axes conjugués et des momens d'inertie des corps. *Journ. de l'Ecole Polyt.* IX. (pp. 41-67.) pp. 45-46.
1811. BINET, J. P. M. Sur quelques formules d'algèbre, et sur leur application à des expressions qui ont rapport aux axes conjugués des corps. *Nouv. Bull. des Sci. par la Soc. Philomatique*, II., pp. 389-392.
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## AMENDMENTS TO FIRST LIST

as printed in

*Quart. Journ. of Math.*, XVIII., pp. 110-149.

- P. 110, l. 35. Add " §257, p. 211 : §264, pp. 217, 218."  
 l. 36. Delete " ?".
- p. 111, l. 14. The correct date is 15th Oct., 1810; see Wronski's *Réfutation*, p. 5.  
 l. 42. Add "*Nouv. Annales de Math.* (2) XV., pp. 385-396, 433-451."
- p. 113, l. 18. The line should read "FINCK. P. T. E. *Éléments d'Algèbre* (p. 95). iv. + 544 pp. Strasbourg."
- p. 115, l. 21. Add "*Œuvres* (1) XI. p. 439, XII., pp. 12-20."
- p. 118, l. 32. Add "*Philos. Magazine* (4) XIV., pp. 392- ."
- p. 120, l. 13. For "Schläfli" read "Schläfli."  
 l. 20. After Fiedler insert "viii. - 271 pp."  
 l. 38. Delete " ? ", and before "Paris" insert "x + 224 pp."
- p. 124, l. 21. For "Ferrari" read "Ferrara."
- p. 126, l. 22. For "Dodson" read "Dodgson."  
 l. 38. Add "*Educ. Times*, XIX., p. 280," the date being March, 1867.
- p. 127, l. 33. Add "*Educ. Times*, XXI., p. 139," the date being Sept., 1868.  
 l. 34. For "p. 62" read "62 pp."
- p. 128, l. 4. Delete " ? ", and after "pp." insert "144-146."  
 l. 21. Add "*Educ. Times*, XXIII., pp. 209, 259."
- p. 129, l. 12. For "pp. 22" read "22 pp."  
 l. 17. For "LXXIII." read "LXXIV."
- p. 130, l. 24. For "Munro" read "Monro."  
 l. 9. Add "*Rendic. .... Ist. Lombardo ....* (Milano), V. fasc. 4."  
 l. 32. Add "*Educ. Times*, XXIV., p. 296, XXV., p. 18."
- p. 132, l. 23. Title begins with "Ein neuer."
- p. 133, l. 17. Add "*Educ. Times*, XXVII., pp. 45, 67."  
 l. 25. Add "*Educ. Times*, XXVII., pp. 45, 66."
- p. 134, l. 32. After "Comptes Rendus ...." insert "(Paris), LXXX., pp. 252-255," and delete the rest.
- p. 135, l. 7. Should be under 1878.  
 l. 10. Before "pp." insert "(5) I."  
 l. 38. After "pp." insert "64."
- p. 136, l. 15. For "Teorie" read "Teorin," and for "pp. 121" read "121 pp."
- p. 137, l. 12. Before "Sui" insert "Nota."
- p. 138, l. 6. Add "*Educ. Times*, XXVIII., p. 252."
- p. 140, l. 5. Add "*Educ. Times*, XXX., p. 20."  
 l. 16. Add "*Educ. Times*, XXIX., p. 212," the date being Dec., 1876.

- p. 141, l. 9. Delete " ?".  
 12. Delete " ?".  
 13. For "grad" read "graad."  
 17. For "3-31" read "31-33."  
 p. 142, l. 4. Before "pp." insert "XVI.," and add "p. 344."  
 l. 8. Before "pp." insert "LXXXVI."  
 l. 17. Add "*Educ. Times*, XXXI., p. 161."  
 p. 143, l. 16. Perhaps wrongly placed; the date of the fasciculus is 15th Feb., 1879.  
 p. 145, l. 7. Add "Helsingfors Acta, XI., pp. 257-271."  
 25. Delete the line.  
 38. Add "*Educ. Times*, XXXII., pp. 205, 268."  
 40. For "473" read "463."  
 p. 146, l. 10. Delete " ?".  
 l. 12. After "pp" insert "489-494."  
 l. 20. Add "*Educ. Times*, XXXII., pp. 243, 315."  
 p. 147, l. 13. For "Ventijol" read "Ventéjol."  
 p. 148, l. 41. Title should be "Een stelling omtrent determinanten."

## AMENDMENTS TO SECOND LIST

as printed in

*Quart. Journ. of Math.*, XXI., pp. 299-320.

- P. 301, l. 36. Already given in first list.  
 p. 302, l. 37. Add "*Math. from Educ. Times*, (2) II., p. 95."  
 p. 303, l. 28. Add "*Educ. Times*, LV., p. 437; *Math. from Educ. Times*, (2) III., p. 82."  
 p. 304, l. 30. Add "*Educ. Times*, LII., p. 338."  
 p. 311, l. 24. Already given on p. 310.  
 p. 312, l. 1. For "Sur" read "Sui"; l. 2, for "de" read "di".  
 p. 313, l. 22. Add "*Bull. des sci. math.* (2) XI. (2) pp. 102-107."  
 l. 41. After "Annales" insert "de Math.", and for "401-410" read "401-409, 556-560."  
 p. 314, l. 38, 39, 40. Delete; title already given.  
 p. 315, l. 18. For "continuant" read "circulant."  
 l. 19. Add "VIII., p. 215, X., pp. 117-119."  
 p. 316, l. 22. Add "*Educ. Times*, L., p. 194."  
 p. 320, l. 22. Add "*Math. from Educ. Times*, XLV., pp. 85-86."  
 l. 27. Add "*Math. from Educ. Times*, XLVII., p. 107."  
 l. 41. For "44" read "560."

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Leitzmann, H.	C 1900 (under Pascal, E.)
Lémeray, E. M.	C 1896.
Lemonnier, H.	A 1875(2), 79(2); C 79.
Lengauer,	B 1880.
Lerch, M.	C 1893, 99.
Leudesdorf, C.	B 1884, C 93.
Lévy, L.	C 1881.
Lewicky, W.	C 1899.
Lieber, H.	C 1898.
Liers, E.	C 1893.
Ligowski,	A 1861.
Lindelöf, L.	B 1880.
Liouville, J.	C 1846.
Lipschitz, R.	C 1873, 86, 90.
Lit, R. R.	B 1879.
Lodge, A.	C 1883.
Loewy, A.	C 1896, 97, 98(2), 1900.
Longchamps, G. de	C 1883, 91.
Loria, G.	C 1886(3), 88(2), 97, 98.
Lovett, E. O.	C 1897, 98, 99.
Lucas, E.	A 1870, 76, 77; B 77; C 89.
Lüroth, J.	C 1895.

McKenzie, J. L.	A 1876; B 74, 78, 80; C 87.
McLaren, Lord.	C 1899.
McLellan, J. A.	C 1889.
Macloskie, G.	C 1899.
MacMahon, P. A.	C 1893, 94, 1900.
Madsen, V. H. O.	C 1875.
Mainardi, G.	A 1850; B 32, 58.
Majo, L. de.	C 1854.
Malet, J. C.	A 1877; B 82; C 74.
Malmsten, C. J.	A 1862; C 49.
Mansion, P.	A 1874, 75, 76, 77(2), 78(3), 79(5), 80; . B 76, 82, 83, 84(2), 85; C 77, 78(2), 82, 84, 86, 93, 99(2), 1901.
Marchand, [E?]	B 1883; C 88.
Marcolongo, R.	C 1887.
Martin, A.	A 1867; B 77.
Martone, M.	C 1891(2).
Massip, L.	C 1898.
Mathews, G. B.	C 1899.
Mathieu, E.	A 1858.
Matzka, W.	A 1877.
Maupin, G.	C 1894.
Maurer, F.	C 1872.
Mehmke, R.	B 185; C 92(2).
Meier, F.	A 1860.
Meilink, B.	A 1865.
Mellberg, E. J.	A 1876.
Menesson,	A 1878.
Méray, Ch.	B 1884; C 75, 85, 99.
Merino, M.	B 1881.
Mertens, F.	A 1876, 77, 80; B 85; C 72, 87, 89, 90, 99.
Metzler, W. H.	C 1892(2), 93, 97, 98(3), 99.
Meyer, A.	C 1894.
Meyer, Fr.	C 1895, 1900.
Meyer, U. H.	A 1849.
Michel, Ch.	C 1896.
Mikelli, A.	A 1863.
Miller, E.	C 1893.
Miller, G. A.	C 1892, 1900.
Miller, W. J. C.	C 1897.
Minchin, G. M.	A 1871.
Minding, [E.] F. [A.]	C 1829.
Minozzi, A.	A 1878.
Mirza-Nizam.	A 1865.
Mitchell, O. H.	B 1882.
Möbius, A. F.	B 1834.
Mogni, A.	A 1865.
Mola, G.	A 1863, 65.
Molins, H.	C 1839.

- Mollame, V. A 1871, 78; C 81, 92.  
 Monge, G. C 1809.  
 Monro, C. J. A 1872.  
 Montferrier, A. S. de. B 1844.  
 Montessus, R. de. C 1897, 99.  
 Moore, E. H. C 1894, 1900.  
 Morales, C. M. C 1888.  
 Moreno, G. A 1878(2).  
 Morley, F. C 1894.  
 Mouchel, J. C 1888.  
 Müller, E. C 1899.  
 Müller, H. A 1879.  
 Müsebeck, C. C 1898.  
 Muir, Th. A 1872, 73, 74, 77(2), 78, 79;  
 B 77(2), 79, 81(11), 82(7), 83(5), 84(7),  
 85(6);  
 C 79, 81, 82(2), 84, 85, 86(4), 87(5),  
 88(5), 89(7), 90, 91(2), 92(3), 94(2),  
 95, 96(6), 97(4), 98, 99(6), 1900(7).  
 Muirhead, R. F. C 1897.  
 Musso, G. C 1893, 94(2).  
 Muth, P. C 1899.  
 Nachreiner, V. A 1872.  
 Nägelsbach, H. A 1871, 72, 74, 76.  
 Nanson, E. J. A 1877; C 97(3), 98(4), 99(3), 1900.  
 Nekrassof, P. A. C 1886, 92.  
 Netto, E. C 1886, 89, 90, 91(2), 93, 94(2), 95(2),  
 96(2), 98.  
 Neuberg, J. B 1883; C 94(2), 99, 1900.  
 Neumann, C 1868.  
 Neumann, C. A 1868.  
 Newman, F. W. A 1857; C 88.  
 Nielsen, N. C 1896.  
 Niemöller, F. C 1891.  
 Niven, C. A 1878.  
 Noether, M. A 1876, 79(2),; C 95.  
 Novarese, E. B 1882.  
 Novarese, H. C 1890.  
 Oliver, J. E. A 1860.  
 Onofrio, P. C 1872.  
 Ott, A. C 1893.  
 d'Ovidio, E. A 1863, 65, 76, 77; C 77, 90.  
 Padova, E. A 1868.  
 Paige, C. le. A 1877, 78(2), 79(4), 80(3),;  
 B 80, 81(3), 82, 84; C 80.  
 Painlevé, P. C 1894.  
 Painvin, L. A 1858(2), 74.

Palmström, A.	C 1888, 90. [One paper entered twice.]
Panton, A. W.	C 1899.
Papelier, G.	C 1897.
Pascal, E.	C 1896(3), 97, 1900.
Pasch, M.	A 1874(2), 79; C 81, 90, 93.
Peano, G.	C 1889(2), 97.
Peck, W. G.	C 1887.
Peirce, J. M.	A 1855; C 99.
Pellet, A. E.	C 1881.
Pelnár, M.	A 1877.
Philastre,	C 1892.
Philippoff, M.	C 1892.
Philippot, I. H.	C 1898.
Picquet, E.	A 1875, 78(3), 80.
Picquet, H.	C 1894.
Pincherle, S.	B 1881; C 83, 97.
Pleskot, A.	C 1896.
Poincaré, H.	C 1886.
Pokorný, M.	A 1865.
Polignac, Prince C. de	A 1868.
Pomey, E.	C 1888, 90.
Posse, C.	B 1883.
Poujade,	C 1887.
Powel, A.	C 1888.
Prado, G. F. de	C 1890.
Prang, C.	C 1900.
Prange, A. J. N.	C 1890.
Prasse, M. v.	C 1811.
Pratt, O.	A 1878.
Presle, A. de.	C 1886.
Prime, F. Mme. Vø.	C 1898(2), 93. [Real name <i>A. Mineur</i> .]
Pringsheim, A.	C 1898.
Prony, R.	C 1795.
Proubet, P.	C 1899.
Prouhet, E.	A 1852, 56, 57.
Prym, F.	C 1892.
Puchta, A.	A 1877; B 81.
<b>Raabe, J. L.</b>	C 1858.
Rados, G.	C 1886(2), 91(3), 96(2), 97, 98(2), 1900.
Rahnsen, A. E.	C 1888.
Raimondi,	C 1888.
Rajola, L.	A 1864, 66.
Ramus, Ch.	A 1856.
Raschi, E.	B 1872.
Ravut, L.	C 1894, 98.
Re, A. de.	B 1881.
Rehorovsky, V.	B 1882.
Reidt, F.	A 1874.

- Reiss, M. A 1829, 38, 67.  
 Renshaw, A. A 1866; C 66.  
 Reuschle, C. B 1884; C 97.  
 Richelot, F. J. C 1840.  
 Ritsert, E. A 1872.  
 Roberts, E. H. C 1896.  
 Roberts, M. A 1859(2), 61, 64.  
 Roberts, S. A 1874, 79.  
 Robinson, L. W. C 1889.  
 Roe, E. D. C 1898(2).  
 Rogers, L. J. C 1886, 91.  
 Rosanes, J. A 1872.  
 Rosenhain, G. A 1847; C 44, 45.  
 Rothe, H. A. A 1800.  
 Rouché, E. B 1858; C 75, 77, 80.  
 Roussiane, (See Russian.)  
 Rubini, R. A 1857, 66, 78; C 67, 73.  
 Runge, C. B 1882.  
 Rusjan, (See Russian.)  
 Russell, A. C 1887, 88.  
 Russell, J. W. C 1897.  
 Russell, W. H. L. C 1885.  
 Russian, C. K. C 1892, 97, 99(2).  
  
 Saalschütz, L. C 1892.  
 Sachse, A. B 1882.  
 Sainte-Marie, C. F. C 1900.  
 Saint-Venant, de. A 1853.  
 Salmon, G. A 1859, 63, 66, 68, 76, 77; B 52, 85.  
 Sampson, R. A. C 1897.  
 Sardi, C. A 1864(2), 65, 66, 67, 68.  
 Sauvage, L. C 1895.  
 Scarpis, U. C 1898, 99.  
 Schapira, H. B 1881(2); C 81, 92, 93.  
 Scheibner, W. A 1859; C 88.  
 Schellbach, K. H. A 1856.  
 Schendel, L. C 1885(2), 87, 91(2).  
 Schering, E. A 1877; C 78.  
 Scherk, H. F. C 1825.  
 Schicht, F. C 1896.  
 Schläfli, L. A 1851, 55, 59.  
 Schlegel, V. C 1894.  
 Schlesinger, L. C 1899.  
 Schlömilch, O. A 1856.  
 Schmidt, H. C 1900.  
 Schmitz, A. C 1880.  
 Scholtz, A. C 1877, 78.  
 Schoute, P. H. C 1892(2).  
 Schrader, W. B 1884; C 86.  
 Schröder, E. A 1875.

- Schulze, E. A 1871; C 97, 99.  
 Schumacher, J. C 1894.  
 Schwarz, H. A. B 1880.  
 Schweins, F. B 1825.  
 Scott, R. F. A 1878, 79(4), 80(2); B 81(3), 82(3).  
 Seeliger, H. A 1875.  
 Segar, H. W. C 1890, 91, 92(5), 93(2).  
 Serdobinsky, V. E. C 1877.  
 Sersawy, V. A 1878.  
 Sharp, W. J. C. C 1887(2), 88, 91(3), 94.  
 Siacci, F. A 1865, 72(4).  
 Sibirani, F. C 1900.  
 Sickenberger, A. B 1885; C 87.  
 Siebeck, F. H. A 1862.  
 Simmons, T. C. C 1885.  
 Simonnet, . C 1879.  
 Smet-Jamar, A 1864.  
 Smith, H. J. S. A 1861, 73, 76; C 62.  
 Soldan, W. A 1877 (see Dölp, 1873).  
 Souillart, C. A 1858, 60.  
 Sourander, E. A 1879.  
 Sperling, J. F. de. A 1858, 60.  
 Sporer, B. C 1887(2).  
 Spottiswoode, W. A 1851, 53, 72, 76.  
 Stäckel, P. C 1896(2).  
 Stahl, W. C 1889.  
 Starkoff, A. C 1884.  
 Stephanos, C. C 1898, 1900.  
 Stern, M. A. A 1865, 71.  
 Sterneck, R. D. v. C 1895.  
 Stickelberger, L. A 1877.  
 Stieltjes, T. J. C 1884, 85, 87, 88.  
 Stockwell, J. N. A 1860.  
 Stodockiewicz, J. C 1879.  
 Stoffaës, . C 1897.  
 Stroh, E. C 1889.  
 Studnicka, F. J. A 1869, 72(4), 73(2), 74, 75, 76(4),  
 77(3), 78, 79;  
 B 78, 79, 80(2), 84(2);  
 C 86(3), 88(2), 96(3), 97(5), 98(9), 99(6),  
 1900.  
 Suarez, A. B 1882.  
 Sylvester, J. J. A 1840, 50(3), 51(4), 52(3), 53(4), 55,  
 63(3), 67, 78, 79(4), 80;  
 B 52, 78, 80, 81, 82(5), 83(3), 84, 85(2);  
 C 39, 41, 51, 53, 79, 84(2), 86, 89(3),  
 90(2), 92.  
 Szil C 1888, 90(2), 95, 98.

- Taber, H.** C 1890, 91, 93(2), 95(2), 96(3).  
**Tait, P. G.** A 1861, 66; C 96.  
**Tanner, H. W. L.** A 1877, 78, 79; B 79; C 78.  
**Tarleton, A.** A 1868; C 87.  
**Tartinville, A.** C 1885, 86.  
**Taylor, W. W.** C 1895.  
**Teixeira, F. G.** A 1877; B 80, 81.  
**Teixeira, J. P.** C 1893(3).  
**Terquem, O.** A 1842, 46, 51, 60, 64; C 46.  
**Thiele, T. N.** A 1869, 70.  
**Thomson, W.** B 1881.  
**Thyagaragaiyar, V. R.** C 1899.  
**Tirelli, F.** A 1874, 75.  
**Tissot, A.** A 1852; C 90.  
**Todhunter, I.** A 1861; C 67.  
**Torelli, G.** A 1864, 65, 66; B 82; C 64, 86(2).  
     93.  
**Transon, A.** A 1874.  
**Traverso, N.** C 1898.  
**Trudi, N.** A 1862(2), 64.  
**Trzaska, W.** A 1870; B 71; C 70.  
**Tucker, R.** C 86, 94(2), 95.  
**Tweedie, Ch.** C 1900.  
**Tyler, H. W.** C 1891.  
  
**Unterhuber, .** A 1872; C 70.  
  
**Vahlen, K. T.** C 1893.  
**Valentiner, H.** C 1898.  
**Valeriano, V.** A 1871, 76; C 71.  
**Vályi, J.** C 1887.  
**Vandermonde, N.** A 1771; C 1770, 1888 (under Itzigsohn).  
**Van Velzer, C. A.** B 1882(2), 83.  
**Vautré, [L?]** C 1893.  
**Veltmann, W.** A 1871; C 86.  
**Ventéjols.** A 1880; C 77.  
**Versluys, J.** C 1870, 71.  
**Visnya, A.** C 1898.  
**Vivanti, G.** C 1890, 97, 98, 1900.  
**Vleck, E. B. v.** C 1899.  
**Voigt, W.** C 1882.  
**Voss, A.** A 1877(2); C 84, 85, 86, 87, 89(3), 90.  
  
**Waelsch, E.** C 1891, 98.  
**Wageningen, v.** A 1871 (under Hesse, O.).  
**Walecki,** B 1882, 84.  
**Walker, J. J.** A 1865, 69, 72, 79.  
**Ward, P. C.** B 1885(2); C 86.  
**Warner, J. D.** C 1881.  
**Weber, H.** C 1895, 98.

Weichhold, G.	C 1893.
Weihrauch, K.	A 1871, 74, 76, 80(2); C 87, 89(2).
Weill, [G.].	C 1888.
Weld, L. G.	C 1893.
Welsch,	C 1896.
Weltzien, C.	C 1892, 97(2).
Wentworth, G. A.	C 1889.
West, E.	C 1886.
Weyr, Ed.	B 1880; C 84, 89.
Weyrauch, J. J.	A 1871.
White, H. S.	C 1895, 99.
Whitworth, W. A.	A 1865, 72.
Williamson, B.	A 1872.
Wisselink, D. B.	A 1877.
Wolstenholme, J.	A 1870, 74, 79; B 84; C 86.
Woodall, H. J.	C 1894.
Woolhouse, W. S. B.	A 1876.
Worontzoff,	C 1892, 93.
Worpitzky, J.	B 1865.
Wright, W. J.	A 1875.
Wronski, H.	A 1811, 15; C 12.
Young, A.	C 1899.
Young, W. H.	C 1898.
Zahradnik, K.	A 1878.
Zajackowski, W. v.	A 1866, 80; C 80(2).
Zantschewsky, J. M.	C 1894.
Zbrozek, D.	C 1884.
Zehfuss, G.	A 1858(4), 59, 62(2), 68.
Zeipel, V. v.	A 1858, 62, 65, 71.
Zelewski, A. v.	A 1870, 77.
Zeuthen, H. G.	C 1874.
Zmurko, L.	A 1866, 71.

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### 13.—A GENERAL THEOREM GIVING EXPRESSIONS FOR CERTAIN POWERS OF A DETERMINANT.

BY THOMAS MUIR, LL.D.

1. In the "Philosophical Magazine" for October, 1902, use was made of an unproved theorem giving the  $(n+1)$ th power of any determinant of the  $n$ th order in the form of a determinant of the order  $\frac{1}{2}n(n+1)$ , any reference to the proof being purposely delayed because of uncertainty as to the history of the theorem. The object of the present note is to remove this uncertainty, and at the same time to merge the theorem in a much more general one the demonstration of which is given.

2. It would appear that the first noted case of the theorem, viz., that in which  $n=3$ , is due to A. Brill, who in his paper "Ueber diejenigen Curven eines Büschels, welche eine gegebene Curve zweipunktig berühren," (*Math. Annalen*, III., pp. 459-468, year 1870-1) made use of it for the purpose of effecting a transformation upon a certain covariant intimately bound up with the geometrical subject he was dealing with. Denoting the determinant

$$\begin{vmatrix} a_1^2 & a_2^2 & a_3^2 & 2a_2a_3 & 2a_3a_1 & 2a_1a_2 \\ b_1^2 & b_2^2 & b_3^2 & 2b_2b_3 & 2b_3b_1 & 2b_1b_2 \\ c_1^2 & c_2^2 & c_3^2 & 2c_2c_3 & 2c_3c_1 & 2c_1c_2 \\ b_1c_1 & b_2c_2 & b_3c_3 & b_2c_3 + b_3c_2 & b_3c_1 + b_1c_3 & b_1c_2 + b_2c_1 \\ c_1a_1 & c_2a_2 & c_3a_3 & c_2a_3 + c_3a_2 & c_3a_1 + c_1a_3 & c_1a_2 + c_2a_1 \\ a_1b_1 & a_2b_2 & a_3b_3 & a_2b_3 + a_3b_2 & a_3b_1 + a_1b_3 & a_1b_2 + a_2b_1 \end{vmatrix}$$

by  $\Delta_6$ , and multiplying row-wise by

$$\begin{vmatrix} 1 & . & . & . & . & . \\ . & 1 & . & . & . & . \\ . & . & 1 & . & . & . \\ 2|b_2c_3| & . & . & . & |b_1c_2| & |b_3c_1| \\ . & 2|b_3c_1| & . & |b_1c_2| & . & |b_2c_3| \\ . & . & 2|b_1c_2| & |b_3c_1| & |b_2c_3| & . \end{vmatrix}$$

he obtained

$$\begin{vmatrix} a_1^2 & a_2^2 & a_3^2 & 2a_1|a_1b_2c_3| & 2a_2|a_1b_3c_3| & 2a_3|a_1b_2c_3| \\ b_1^2 & b_2^2 & b_3^2 & . & . & . \\ c_1^2 & c_2^2 & c_3^2 & . & . & . \\ b_1c_1 & b_2c_2 & b_3c_3 & . & . & . \\ c_1a_1 & c_2a_2 & c_3a_3 & c_1|a_1b_2c_3| & c_2|a_1b_2c_3| & c_3|a_1b_2c_3| \\ a_1b_1 & a_2b_2 & a_3b_3 & b_1|a_1b_2c_3| & b_2|a_1b_2c_3| & b_3|a_1b_2c_3| \end{vmatrix}.$$

and thus arrived at the equation

$$\Delta_6 \cdot 2 \cdot |b_1c_2| \cdot |b_2c_3| \cdot |b_3c_1| = 2 \cdot |a_1b_2c_3|^4 \cdot \begin{vmatrix} b_1^2 & b_2^2 & b_3^2 \\ c_1^2 & c_2^2 & c_3^2 \\ b_1c_1 & b_2c_2 & b_3c_3 \end{vmatrix},$$

whence, on account of the determinant on the extreme right being equal to  $|b_1c_2| \cdot |b_2c_3| \cdot |b_3c_1|$ , it followed that

$$\Delta_6 = |a_1b_2c_3|^4.$$

3. About seven and a half years later the same special case was utilized by A. Scholtz, of Buda-Pest, in his paper "Sechs Punkte eines Kegelschnittes" (*Archiv d. Math. u. Phys.* LXII., pp. 317-324, year 1878). Scholtz gave no reference to Brill, of whose paper he was most probably unaware, but established the result for himself. The first row of the determinant he modified by multiplying each element of it by  $|b_2c_3|$  and adding to the product  $|a_2b_3|$  times the corresponding element of the fifth row and  $|c_2a_3|$  times the corresponding element of the sixth row; the second and third rows were modified in like manner. This, on putting

$$D = |a_1b_2c_3|,$$

led to

$$\begin{aligned} \Delta_6 \cdot |b_2c_3| \cdot |c_2a_3| \cdot |a_2b_3| &= \begin{vmatrix} a_1D & . & . & . & a_3D & a_2D \\ b_1D & . & . & . & b_3D & b_2D \\ c_1D & . & . & . & c_3D & c_2D \\ b_1c_1 & b_2c_2 & b_3c_3 & b_2c_3 + b_3c_2 & b_2c_1 + b_1c_3 & b_1c_2 + b_2c_1 \\ c_1a_1 & c_2a_2 & c_3a_3 & c_2a_3 + c_3a_2 & c_3a_1 + c_1a_3 & c_1a_2 + c_2a_1 \\ a_1b_1 & a_2b_2 & a_3b_3 & a_2b_3 + a_3b_2 & a_3b_1 + a_1b_3 & a_1b_2 + a_2b_1 \end{vmatrix} \\ &= -D^4 \begin{vmatrix} b_2c_2 & b_3c_3 & b_2c_3 + b_3c_2 \\ c_2a_2 & c_3a_3 & c_2a_3 + c_3a_2 \\ a_2b_2 & a_3b_3 & a_2b_3 + a_3b_2 \end{vmatrix}, \end{aligned}$$

and all that remained was to show that the three-line determinant on the right is equal to  $-|b_2c_3| \cdot |c_2a_3| \cdot |a_2b_3|$ .

4. Strictly speaking the difference between the two proofs is less even than might at first appear, for the modification effected by Scholtz upon the first three rows can be accomplished exactly after Brill's fashion, viz., by multiplying column-wise by

$$\begin{vmatrix} |b_2c_3| & . & . & . & . & . \\ . & |c_2a_3| & . & . & . & . \\ . & . & |a_2b_3| & . & . & . \\ . & |a_2b_3| & |c_2a_3| & \text{I} & . & . \\ |a_2b_3| & . & |b_2c_3| & . & \text{I} & . \\ . & |b_2c_3| & . & . & . & \text{I} \end{vmatrix},$$

and, if this change were made, we might contrast them by saying that while the one reduces to zero  $3^2$  elements in the last three columns, the other does the same in the first three rows.

5. The third paper which concerns our subject emanated from the same city as the second, viz., Buda-Pest, its author being Hunyady, and its title "Beitrag zur Theorie des Flächen zweiten Grades." It appeared in Crelle's Journal, LXXXIX., pp. 47-69, about the beginning of 1880, but is dated July, 1879, so that it must have been written about a year after the publication of Scholtz's results. It is in part merely the natural extension to three-dimensional space of Scholtz's theorems in plane geometry, and there are features of it which suggest acquaintance with what Scholtz had done, but, although references to previous workers are numerous, the name of Scholtz is not anywhere mentioned in it.

The determinant,  $\Delta_{10}$  say, to which Hunyady was, of course, led, is

$$\begin{vmatrix} a_1^2 & a_2^2 & a_3^2 & a_4^2 & 2a_1a_2 & 2a_1a_3 & 2a_1a_4 & 2a_2a_3 & 2a_2a_4 & 2a_3a_4 \\ b_1^2 & b_2^2 & : & : & 2b_1b_2 & : & : & : & : & : \\ c_1^2 & c_2^2 & : & : & 2c_1c_2 & : & : & : & : & : \\ d_1^2 & d_2^2 & & & 2d_1d_2 & & & & & \\ a_1b_1 & a_2b_2 & & & a_1b_2 + a_2b_1 & & & & & \\ a_1c_1 & : & & & a_1c_2 + a_2c_1 & & & & & \\ a_1d_1 & : & & & a_1d_2 + a_2d_1 & & & & & \\ b_1c_1 & & & & b_1c_2 + b_2c_1 & & & & & \\ b_1d_1 & & & & b_1d_2 + b_2d_1 & & & & & \\ c_1d_1 & & & & c_1d_2 + c_2d_1 & & & & & \end{vmatrix}.$$

This he treats in exactly the same manner as Scholtz had treated  $\Delta_6$ , the penultimate equation of the process being

$$\Delta_{10} \cdot |b_2c_3d_4| \cdot |a_2c_3d_4| \cdot |a_2b_3d_4| \cdot |a_2b_3c_4| = - |a_1b_2c_3d_4|^5 \cdot P,$$

where P stands for the determinant

$$\begin{vmatrix} a_3b_2 & a_3b_3 & a_4b_4 & a_2b_3 + a_3b_2 & a_2b_4 + a_4b_3 & a_3b_4 + a_4b_3 \\ a_2c_2 & a_3c_3 & a_4c_4 & a_2c_3 + a_3c_2 & a_2c_4 + a_4c_2 & a_3c_4 + a_4c_3 \\ a_2d_2 & a_3d_3 & a_4d_4 & a_2d_3 + a_3d_2 & a_2d_4 + a_4d_2 & a_3d_4 + a_4d_3 \\ b_2c_2 & b_3c_3 & b_4c_4 & b_2c_3 + b_3c_2 & b_2c_4 + b_4c_2 & b_3c_4 + b_4c_3 \\ b_2d_2 & b_3d_3 & b_4d_4 & b_2d_3 + b_3d_2 & b_2d_4 + b_4d_2 & b_3d_4 + b_4d_3 \\ c_2d_2 & c_3d_3 & c_4d_4 & c_2d_3 + c_3d_2 & c_2d_4 + c_4d_2 & c_3d_4 + c_4d_3 \end{vmatrix};$$

which he says can be shown to be equal to

$$- |b_2c_3d_4| \cdot |a_2c_3d_4| \cdot |a_2b_3d_4| \cdot |a_2b_3c_4|.$$

6. The general theorem which includes Hunyady's case regarding  $\Delta_{10}$ , Brill's and Scholtz's regarding  $\Delta_6$ , and the still simpler case

$$\Delta_3 = \begin{vmatrix} a_1^2 & a_2^2 & 2a_1a_2 \\ b_1^2 & b_2^2 & 2b_1b_2 \\ a_1b_1 & a_2b_2 & a_1b_2 + a_2b_1 \end{vmatrix} = |a_1b_2|^3,$$

is formally enunciated by Pascal in his text-book "I Determinanti," published at Milan in 1897 (see pp. 134-137). A separate section (§ 26) is devoted to it; but, strange to say, the heading of the section is "Teorema di Hunyady," a name which apparently\* he has taken over from Igel and Escherich, but which in view of what precedes he will surely reconsider.

7. Be this as it may, let it now be noted that if the point of view in regard to the theorem be entirely changed, so that we look upon the determinants in question as *eliminants*, a striking advantage is gained, the following general theorem being at once reached:—

*If a set of n homogeneous equations of the first degree in n unknowns be given, the determinant of the set being  $\Delta$ , and there be formed another set consisting of all equations of the  $\rho^{\text{th}}$  degree derivable from the equations of the given set by multiplication among themselves, the determinant of the latter set is equal to*

$$\Delta^{C_{\rho+n-1, n}}.$$

By way of proof we note in the first place that the number specifying the order of the derived determinant is the number of arrangements of  $n$  things taken  $\rho$  at a time with repetitions allowed, and therefore is  $C_{n+\rho-1, \rho}$ : secondly, that the degree of each element of this determinant is  $\rho$ : and consequently that the degree of each term of the finally expanded determinant is

$$\rho \cdot C_{n+\rho-1, \rho}.$$

Further we note that on account of the mode in which the second set of equations is derived from the original set, the eliminant of the second set cannot contain any factor extraneous to the eliminant of the first set nor give prominence to any factor of the first set over any other, and consequently that the former eliminant must be an integral power of the latter. As the degree of each term of the latter is  $n$  and of the former  $\rho \cdot C_{n+\rho-1, \rho}$ , the index of the power referred to must therefore be

$$\frac{\rho}{n} \cdot C_{n+\rho-1, \rho}$$

$$\text{i.e.} \quad \frac{\rho}{n} \cdot C_{n+\rho-1, n-1}$$

$$\text{i.e.} \quad C_{n+\rho-1, n},$$

as was to be shown.

The theorem used in the *Phil. Mag.* for October, 1902, and formulated by Pascal in his text-book is the case of this where  $\rho=2$ .

\* Their papers in the *Monatshefte f. Math. u. Phys.* III. pp. 55-67, 68-80, † been able to see.

# 14.—THEOREMS REGARDING AGGREGATES OF DETERMINANTS AND PFAFFIANS.

BY THOMAS MUIR, LL.D.

1. Of several familiar results, each of which may be made the starting point for an exposition of the theorems here to be dealt with, the least likely, in view of the title, is the identity

$$U = \frac{1}{2}x \frac{\partial U}{\partial x} + \frac{1}{2}y \frac{\partial U}{\partial y} + \frac{1}{2}z \frac{\partial U}{\partial z}, \quad (A)$$

where  $U$  is any homogeneous function of  $x, y, z$  of the second degree. Nevertheless, if for  $U$  we take

$$ax^2 + by^2 + cz^2 + 2fyz + 2gzx + 2hxy$$

or, as it is best written in order to show its discriminant,

$$\begin{array}{ccc|c} x & y & z & \\ a & h & g & x \\ h & b & f & y \\ g & f & c & z, \end{array}$$

it will be found that each of the terms on the right of (A) may be expressed as a determinant: the unlikelihood is thus at once considerably diminished. The identity then becomes

$$\begin{array}{ccc|c} x & y & z & \\ a & h & g & x \\ h & b & f & y \\ g & f & c & z \end{array} = \begin{vmatrix} a & z & -y \\ h & . & x \\ g & -x & . \end{vmatrix} + \begin{vmatrix} . & h & -y \\ -z & b & x \\ y & f & . \end{vmatrix} + \begin{vmatrix} . & z & g \\ -z & . & f \\ y & -x & c \end{vmatrix},$$

where, be it observed, each of the three determinants is formable by taking two columns from the zero-axial skew determinant

$$\begin{vmatrix} . & z & -y \\ -z & . & x \\ y & -x & . \end{vmatrix}$$

and one from the discriminant of the quadric.

2. If  $P$  be any  $n$ -line determinant,  $Q$  a zero-axial skew determinant of the same order, and  $\Delta_r$  a determinant formed by replacing the  $r^{\text{th}}$  column of  $Q$  by the  $r^{\text{th}}$  column of  $P$ , then, when  $n$  is odd,

$$\sum_{r=1}^{r=n} \Delta_r = \begin{vmatrix} \mu_1 & -\mu_2 & \mu_3 & -\mu_4 & \dots \\ & P & & & \\ & & \mu_1 & & \\ & & -\mu_2 & & \\ & & & \ddots & \end{vmatrix}$$

where  $\mu_1, \mu_2, \dots$  are the minors obtained by deleting the 1<sup>st</sup>, 2<sup>nd</sup>, ... frame-lines of the quasi-pfaffian of  $Q$ .

For the sake of shortness in writing let the given determinants be of the *fifth* order, viz. :—

$$\begin{vmatrix} a_1 & a_2 & a_3 & a_4 & a_5 \\ b_1 & b_2 & b_3 & b_4 & b_5 \\ c_1 & c_2 & c_3 & c_4 & c_5 \\ d_1 & d_2 & d_3 & d_4 & d_5 \\ e_1 & e_2 & e_3 & e_4 & e_5 \end{vmatrix}, \quad \begin{vmatrix} . & \beta_2 & \beta_3 & \beta_4 & \beta_5 \\ -\beta_2 & . & \gamma_3 & \gamma_4 & \gamma_5 \\ -\beta_3 & -\gamma_3 & . & \delta_4 & \delta_5 \\ -\beta_4 & -\gamma_4 & -\delta_4 & . & \epsilon_5 \\ -\beta_5 & -\gamma_5 & -\delta_5 & -\epsilon_5 & . \end{vmatrix};$$

and let the pfaffian minors of the latter,

$$\begin{vmatrix} \gamma_3 & \gamma_4 & \gamma_5 \\ \delta_4 & \delta_5 \\ \epsilon_5 \end{vmatrix}, \quad \begin{vmatrix} \beta_3 & \beta_4 & \beta_5 \\ \delta_4 & \delta_5 \\ \epsilon_5 \end{vmatrix}, \quad \begin{vmatrix} \beta_3 & \beta_4 & \beta_5 \\ \gamma_4 & \gamma_5 \\ \epsilon_5 \end{vmatrix}, \quad \begin{vmatrix} \beta_3 & \beta_4 & \beta_5 \\ \gamma_3 & \gamma_5 \\ \delta_5 \end{vmatrix}, \quad \begin{vmatrix} \beta_3 & \beta_4 & \beta_5 \\ \gamma_3 & \gamma_4 \\ \delta_4 \end{vmatrix},$$

be denoted by  $\mu_1, \mu_2, \dots, \mu_5$ ; then the first term of the aggregate referred to in the enunciation is

$$\begin{vmatrix} a_1 & \beta_2 & \beta_3 & \beta_4 & \beta_5 \\ b_1 & . & \gamma_3 & \gamma_4 & \gamma_5 \\ c_1 & -\gamma_3 & . & \delta_4 & \delta_5 \\ d_1 & -\gamma_4 & -\delta_4 & . & \epsilon_5 \\ e_1 & -\gamma_5 & -\delta_5 & -\epsilon_5 & . \end{vmatrix}$$

which being a "bordered" skew determinant is by reason of Cayley's theorem resolvable into

$$\begin{vmatrix} a_1 & b_1 & c_1 & d_1 & e_1 \\ \beta_2 & \beta_3 & \beta_4 & \beta_5 \\ \gamma_3 & \gamma_4 & \gamma_5 \\ \delta_4 & \delta_5 \\ \epsilon_5 \end{vmatrix} \cdot \begin{vmatrix} \gamma_3 & \gamma_4 & \gamma_5 \\ \delta_4 & \delta_5 \\ \epsilon_5 \end{vmatrix},$$

and therefore into

$$(a_1\mu_1 - b_1\mu_2 + c_1\mu_3 - d_1\mu_4 + e_1\mu_5) \cdot \mu_1.$$

The other terms are similarly shown to be equal to

$$\begin{aligned} & (-a_2\mu_1 + b_2\mu_2 - c_2\mu_3 + d_2\mu_4 - e_2\mu_5) \cdot \mu_2, \\ & (a_3\mu_1 - b_3\mu_2 + c_3\mu_3 - d_3\mu_4 + e_3\mu_5) \cdot \mu_3, \\ & (-a_4\mu_1 + b_4\mu_2 - c_4\mu_3 + d_4\mu_4 - e_4\mu_5) \cdot \mu_4, \\ & (a_5\mu_1 - b_5\mu_2 + c_5\mu_3 - d_5\mu_4 + e_5\mu_5) \cdot \mu_5; \end{aligned}$$

and thus the sum of them all is

$$\begin{array}{ccccc|c} \mu_1 & -\mu_2 & \mu_3 & -\mu_4 & \mu_5 & \\ a_1 & b_1 & c_1 & d_1 & e_1 & \mu_1 \\ a_2 & b_2 & c_2 & d_2 & e_2 & -\mu_2 \\ a_3 & b_3 & c_3 & d_3 & e_3 & \mu_3 \\ a_4 & b_4 & c_4 & d_4 & e_4 & -\mu_4 \\ a_5 & b_5 & c_5 & d_5 & e_5 & \mu_5 \end{array}$$

as was to be proved.

3. If  $P$  be any  $n$ -line determinant,  $Q$  a zero-axial skew determinant of the same order, and  $\Delta_r$  a determinant formed by replacing the  $r^{\text{th}}$  column of  $Q$  by the  $r^{\text{th}}$  column of  $P$ , then when  $n$  is even

$$\sum_{r=1}^{r=n} \Delta_r = \sqrt{Q} \cdot S,$$

$S$  being an aggregate which vanishes when  $P$  is axisymmetric.

If for the purpose of illustrative proof we take

$$P = |a_1 \ a_2 \ a_3 \ a_4 \ a_5 \ a_6| \quad \text{and} \quad Q = \begin{vmatrix} a_2 & a_3 & a_4 & a_5 & a_6 \\ \beta_3 & \beta_4 & \beta_5 & \beta_6 \\ \gamma_4 & \gamma_5 & \gamma_6 \\ \delta_5 & \delta_6 \\ \epsilon_6 \end{vmatrix}^2$$

the first term of  $\Sigma \Delta_r$  is

$$\begin{vmatrix} a_1 & a_2 & a_3 & a_4 & a_5 & a_6 \\ b_1 & . & \beta_3 & \beta_4 & \beta_5 & \beta_6 \\ c_1 & -\beta_3 & . & \gamma_4 & \gamma_5 & \gamma_6 \\ d_1 & -\beta_4 & -\gamma_4 & . & \delta_5 & \delta_6 \\ e_1 & -\beta_5 & -\gamma_5 & -\delta_5 & . & \epsilon_6 \\ f_1 & -\beta_6 & -\gamma_6 & -\delta_6 & -\epsilon_6 & . \end{vmatrix}$$

which by Cayley's theorem previously referred to is resolvable into

$$\begin{vmatrix} a_2 & a_3 & a_4 & a_5 & a_6 \\ \beta_3 & \beta_4 & \beta_5 & \beta_6 \\ \gamma_4 & \gamma_5 & \gamma_6 \\ \delta_5 & \delta_6 \\ \epsilon_6 \end{vmatrix} \cdot \begin{vmatrix} b_1 & c_1 & d_1 & e_1 & f_1 \\ \beta_3 & \beta_4 & \beta_5 & \beta_6 \\ \gamma_4 & \gamma_5 & \gamma_6 \\ \delta_5 & \delta_6 \\ \epsilon_6 \end{vmatrix}$$

and therefore

$$= \sqrt{Q} \{ \quad + b_1.f_{12} - c_1.f_{13} + d_1.f_{14} - e_1.f_{15} + f_1.f_{16} \}.$$

where  $\bar{f}_{12}, \bar{f}_{13}, \dots$  are the cofactors of  $a_2, a_3, \dots$  in  $\sqrt{Q}$ . Similarly it is found that

$$\begin{aligned}\Delta_2 &= \sqrt{Q} \{ -a_2 \bar{f}_{12} \quad \quad + c_2 \bar{f}_{22} - d_2 \bar{f}_{23} + e_2 \bar{f}_{24} - f_2 \bar{f}_{25} \}, \\ \Delta_3 &= \sqrt{Q} \{ a_3 \bar{f}_{13} - b_3 \bar{f}_{23} \quad \quad + d_3 \bar{f}_{33} - e_3 \bar{f}_{34} + f_3 \bar{f}_{35} \}, \\ &\dots\dots\dots\end{aligned}$$

Consequently we have

$$\sum_{r=1}^{r=5} \Delta_r = \sqrt{Q} \cdot S,$$

where  $S$  stands for

$$\begin{aligned}\bar{f}_{12} (b_1 - a_2) - \bar{f}_{13} (c_1 - a_3) + \dots + \bar{f}_{16} (f_1 - a_6) \\ + \bar{f}_{23} (c_2 - b_3) - \dots - \bar{f}_{26} (f_2 - b_6) \\ \dots\dots\dots \\ + \bar{f}_{56} (f_5 - c_6).\end{aligned}$$

— an expression which manifestly vanishes when  $P$  is axisymmetric. The theorem is thus established.

4. It will be observed that in the case of both theorems (§§ 2, 3) each term of the aggregate  $\Sigma \Delta_r$  is expressible as the product of two pfaffians, one of which is dependent only on the elements of  $Q$ , and the other has a frame line of elements taken from  $P$  and the rest from  $Q$ . When  $n$  is odd (§ 2) the pfaffian which is free of the elements of  $P$  is of lower order than the other; when  $n$  is even it is of the same order as the other and besides does not vary for different values of  $r$ .

5. The portion of the theorem of § 3 which relates to the vanishing of the aggregate  $\Sigma \Delta$  can be readily established, without previously removing the factor  $\sqrt{Q}$  from  $\Delta_r$ , by showing that the cofactor of any one of  $P$ 's elements differs only in sign from the cofactor of the conjugate element.

It is also worthy of note that the same result follows from the general theorem\* that if  $D_r$  denote the determinant formed by replacing the  $r^{\text{th}}$  row (not column) of any determinant  $Q$  by the  $r^{\text{th}}$  row of any other determinant  $P$ , then

$$\sum_{r=1}^{r=n} \Delta_r = \sum_{r=1}^{r=n} D_r ;$$

for, in the special case before us, the two equals can be shown to have the same sign and must therefore both vanish.

\* See *Proc. Roy. Soc., Edinburgh*, vol. xv., pp. 96-105.

6. A little examination of the first form of the expression denoted by  $S$  in §3 leads to an important theorem concerning pfaffians only, viz. :—

*If  $P$  and  $Q$  be any  $2n$ -line pfaffians, and  $ff_r$  be the pfaffian whose first frame-line is the  $r^{\text{th}}$  frame-line of  $P$  and whose remaining portion is that got by deleting the  $r^{\text{th}}$  frame-line of  $Q$ , then*

$$\sum_{r=1}^{r=2n} (-1)^r ff_r = 0.$$

For example, taking

$$P = \begin{vmatrix} l & m & n \\ & r & s \\ & & t \end{vmatrix}, \quad Q = \begin{vmatrix} \lambda & \mu & \nu \\ & \rho & \sigma \\ & & \tau \end{vmatrix},$$

we have

$$\begin{vmatrix} l & m & n \\ & \rho & \sigma \\ & & \tau \end{vmatrix} - \begin{vmatrix} l & r & s \\ & \mu & \nu \\ & & \tau \end{vmatrix} + \begin{vmatrix} m & r & t \\ & \lambda & \nu \\ & & \sigma \end{vmatrix} - \begin{vmatrix} n & s & t \\ & \lambda & \mu \\ & & \rho \end{vmatrix} = 0.$$

The basis of the theorem is the fact that each element of  $P$  occurs twice in  $\sum (-1)^r ff_r$  and that its cofactor in one place differs only in sign from its cofactor in the other.

7. If now we reverse the positions of  $P$  and  $Q$  in the theorems of §§2, 3 we arrive at analogous results which can be combined in one enunciation, there being no need to distinguish the case where  $n$  is even from that in which  $n$  is odd. This single theorem may be expressed as follows :—

*If  $P$  be any  $n$ -line determinant,  $Q$  a zero-axial skew determinant of the same order, and if  $\Delta_r$  be the determinant formed by replacing the  $r^{\text{th}}$  column of  $P$  by the  $r^{\text{th}}$  column of  $Q$ , then*

$$\sum_{r=1}^{r=n} \Delta_r$$

*can be so transformed as to show that it vanishes when  $P$  is axisymmetric.*

For example, if  $P$  and  $Q$  be

$$\begin{vmatrix} a_1 & a_2 & a_3 & a_4 \\ b_1 & b_2 & b_3 & b_4 \\ c_1 & c_2 & c_3 & c_4 \\ d_1 & d_2 & d_3 & d_4 \end{vmatrix}, \quad \begin{vmatrix} . & l & m & n \\ -l & . & p & q \\ -m & -p & . & r \\ -n & -q & -r & . \end{vmatrix}$$

we have

$$\sum_{r=1}^{r=4} \Delta_r = \begin{vmatrix} . & a_2 & a_3 & a_4 \\ -l & b_2 & b_3 & b_4 \\ -m & c_2 & c_3 & c_4 \\ -n & d_2 & d_3 & d_4 \end{vmatrix} + \begin{vmatrix} a_1 & l & a_3 & a_4 \\ b_1 & . & b_3 & b_4 \\ c_1 & -p & c_3 & c_4 \\ d_1 & -q & d_3 & d_4 \end{vmatrix} + \dots$$

$$= l(A_2 - B_1) + m(A_3 - C_1) + n(A_4 - D_1)$$

$$+ p(B_3 - C_2) + q(B_4 - D_2)$$

$$+ r(C_4 - D_3),$$

where  $A_1, A_2, \dots$  stand for the cofactors of  $a_1, a_2, \dots$  in  $P$ . The vanishing of this expression when  $|a_1 b_2 c_3 d_4|$  is axisymmetric is assured by the fact that then  $|A_1 B_2 C_3 D_4|$  is axisymmetric also.

8. As an example of the application of such theorems as the preceding let us take the problem of evaluating the determinant of a matrix which is the sum of two vanishing matrices, say the determinant

$$\begin{vmatrix} b^2 + c^2 & -ab + \gamma & -ca + \beta \\ -ba + \gamma & c^2 + a^2 & -bc - a \\ -ca - \beta & -cb + a & a^2 + b^2 \end{vmatrix}$$

where

$$\begin{vmatrix} b^2 + c^2 & -ab & -ca \\ -ba & c^2 + a^2 & -bc \\ -ca & -cb & a^2 + b^2 \end{vmatrix} = 0 = \begin{vmatrix} . & -\gamma & \beta \\ \gamma & . & -a \\ -\beta & a & . \end{vmatrix}$$

Calling these vanishing determinants  $P$  and  $Q$  and viewing the given determinant as having binomial elements in accordance with the composition of its matrix, we may partition it into eight determinants. Of these the first and last being  $P$  and  $Q$  may be neglected. Taking next the three, each of which contains two columns of  $P$  and one of  $Q$ , we know that their sum vanishes by reason of the theorem of §7. There thus only remains to be considered the sum of the three, each of which contains two columns of  $Q$  and one of  $P$ , and this sum by §2 is equal to

$$\begin{array}{ccc|c} \alpha & \beta & \gamma & \\ \hline b^2 + c^2 & -ab & -ac & \alpha \\ -ba & c^2 + a^2 & -bc & \beta \\ -ca & -cb & a^2 + b^2 & \gamma \end{array}$$

An equivalent of the given determinant is thus found.

As we know otherwise\* that the value of the determinant is

$$\begin{vmatrix} a & b \\ a & \beta \end{vmatrix}^2 + \begin{vmatrix} a & c \\ a & \gamma \end{vmatrix}^2 + \begin{vmatrix} b & c \\ \beta & \gamma \end{vmatrix}^2,$$

an expression which is symmetrical with respect to the interchange

$$\begin{pmatrix} a & b & c \\ a & \beta & \gamma \end{pmatrix},$$

we arrive at the following curious series of identities :—

$$\begin{aligned} & \begin{vmatrix} a & b & c \\ a & \beta & \gamma \end{vmatrix}^2 \quad \text{or} \quad \begin{vmatrix} \beta c - b\gamma & a & a \\ \gamma a - c\alpha & \beta & b \\ ab - a\beta & \gamma & c \end{vmatrix} \\ &= \begin{vmatrix} b^2 + c^2 & -ab - \gamma & -ac + \beta \\ -ba + \gamma & c^2 + a^2 & -bc - a \\ -ca - \beta & -cb + a & a^2 + b^2 \end{vmatrix} = \begin{vmatrix} \beta^2 + \gamma^2 & -\beta a - c & -\gamma a + b \\ -\beta a + c & \gamma^2 + a^2 & -\beta \gamma - a \\ -\gamma a - b & -\gamma \beta + a & a^2 + \beta^2 \end{vmatrix}, \\ &= \begin{vmatrix} a & \beta & \gamma \\ b^2 + c^2 & -ab & -ac \\ -ba & c^2 + a^2 & -bc \\ -ca & -cb & a^2 + b^2 \end{vmatrix} a = \begin{vmatrix} a & b & c \\ \beta^2 + \gamma^2 & -a\beta & -a\gamma \\ -\beta a & \gamma^2 + a^2 & -\beta \gamma \\ -\gamma a & -\gamma \beta & a^2 + \beta^2 \end{vmatrix} \begin{vmatrix} a \\ b \\ c \end{vmatrix}. \end{aligned}$$

\* Performing the operations :

$$\text{col}_1 + \frac{b}{a} \text{col}_2 + \frac{c}{a} \text{col}_3, \quad \text{row}_1 + \frac{b}{a} \text{row}_2 + \frac{c}{a} \text{row}_3.$$

and denoting

$$\beta c - b\gamma, \quad \gamma a - c\alpha, \quad ab - a\beta \quad \text{by } A, B, C$$

so that  $aA + bB + cC = 0 = aA + \beta B + \gamma C$  we obtain

$$\begin{vmatrix} . & -\frac{B}{a} & -\frac{C}{a} \\ \frac{B}{a} & c^2 + a^2 & -bc - a \\ \frac{C}{a} & -bc + a & a^2 + b^2 \end{vmatrix},$$

which

$$\begin{aligned} &= \frac{1}{a^2} \{ 2bcBC + C^2(c^2 + a^2) + B^2(a^2 + b^2) \} \\ &= \left( \frac{bB + cC}{a} \right)^2 + C^2 + B^2, \\ &= A^2 + B^2 + C^2. \end{aligned}$$

## 15.—THE DEVELOPMENT OF GOLD EXTRACTION METHODS ON THE WITWATERSRAND.

BY W. A. CALDECOTT, B.A., F.C.S.

The general principles upon which gold extraction work upon the Rand is carried out are so simple, and some acquaintance with them so common, that only a brief outline of the operations as at present conducted will be given. Following upon this, some features in the development of Rand practice, and the considerations which have led to the adoption of present methods will be discussed. Messrs. Williams, Reunert, Yates, and Goldmann have all dealt in some detail with recovery methods as practised on the Rand, and to the works of these members of our Association I would refer any one desirous of further information.

The ore as it comes from the mine is mechanically tipped over a "grizzly" or inclined screen composed of parallel bars at short distances apart. By this means it is separated into "fines" and "coarse." The former pass at once to the mill, whilst the latter, after washing by a spray of water, gravitates to a belt or rotating circular table, where the pieces of rock other than banket are picked out by hand, and eventually find their way to a waste dump. The auriferous banket is delivered automatically to huge breakers, which reduce it to pieces not exceeding  $2\frac{1}{2}$ " in diameter, and it then passes into trucks, which convey it to the mill bins. From the bins it gravitates through automatic feeders into the batteries, where it is crushed. The mill consists of a series of 5-stamp batteries; a battery comprises five stamps, each weighing one-half to two-thirds of a ton. Each stamp is lifted and allowed to fall from a height of about eight inches nearly a hundred times a minute upon the ore resting on the dies, contained in what is called a mortar-box. As the ore is automatically delivered into the mortar-box about seven times its weight of water is also allowed to flow in, and the pulp produced by crushing is splashed against a screen of 600 to 1,000 holes per square inch in the front of the mortar-box. As may be imagined the noise in a stamp mill is tremendous and all conversation in the building impossible. Heard from a distance it much resembles the roar of breakers on the sea-shore. As the ore is gradually reduced to a sufficient degree of fineness it is carried by the water through the screen and travels as pulp over inclined amalgamated copper plates, to which the liberated coarser metallic gold adheres and is periodically scraped off as amalgam. The amalgam contains about two-thirds of its weight of mercury which is recovered for re-use by retorting, and the spongy metallic gold left after this operation cast into bars. The bullion thus obtained usually contains about

87 % to 88 % fine gold, 10 % to 12 % silver and a little copper or other traces of base metal. By means of the amalgamation process above described 50 % to 60 % of the gold contents of the ore is recovered, and the remainder contained in the tailings flows as pulp to the cyanide plant. What is now considered a modern Rand stamp-mill contains 200 stamps, and each stamp crushes about  $5\frac{1}{2}$  tons of ore per 24 hours, so that, allowing for stoppages, upwards of 30,000 tons of ore are crushed per month. Before the war about 6,000 stamps were erected on the Witwatersrand, and this number is likely to be doubled in a few years, if a sufficient supply of cheap unskilled labour is forthcoming.

The pulp leaving the mill is elevated by a tailings wheel or pump and then flows into a spitzlutte or crude hydraulic classifier, which separates out the heavier and richer pyritic material. The concentrates thus produced are settled in vats, the poorer finer sands remaining are collected in other vats, and the residual slimes or unpalpably fine portion of the crushed ore is collected, after mixing with lime to assist settlement, in still a third set of vats with conical bottoms. The water only remains and is returned to the mill for re-use. The tailings from typical half-ounce Rand ore thus treated would yield about 10 % of 12 dwt. concentrates, 65 % of 4 dwt. sands, and 25 % of  $2\frac{1}{2}$  dwt. slimes. The concentrates and sands, being porous permeable products, are treated by leaching for several days with dilute cyanide solution in vats provided with false filter-cloth bottoms. The cyanide solution gradually dissolves and washes out the gold, and the drainings are passed through long rectangular zinc boxes provided with several compartments containing lead-coated zinc shavings upon which the gold is precipitated. The solution flows on into sumps, where it is made up to the requisite strength by addition of solid cyanide and used again for fresh charges. The slimes being non-leachable are treated by mixing with very dilute cyanide solution, allowing to settle, decanting off the clear supernatant gold-bearing solution and repeating this operation as often as their richness warrants. The gold is precipitated from the auriferous slimes solution in the same way as that from the sands or concentrates. The finely divided metallic gold precipitated on the zinc shavings is periodically washed off through a screen and, after treating with dilute sulphuric acid to remove the fine zinc mixed with it, is calcined, smelted with flux and refining agents, and cast into bars.

The percentage recovery in the cyanide plant depends to some extent upon how much gold has already been removed by the mill, but assuming that 57 % of the total gold has been recovered by amalgamation about 33 % further is recovered by cyaniding. Hence the combined extraction by the mill and cyanide plant is about 90 %, or 9 dwts. per ton from half-ounce ore and this is effected in a modern plant at a total cost for all reduction and recovery charges of about 6/- to 7/- per ton, or less than the value of 2 dwts. of bullion.

The tailings after their treatment as described are called residues, and their accumulation in immense piles of sand after removal from

the plant constitutes a prominent feature on the surface of all mining properties.

To illustrate the advances made in methods of gold extraction on the Rand since its early days, the plant and methods employed during 1889, the year immediately preceding the introduction of the cyanide process by John Stewart MacArthur, may be compared with the present state of affairs. The comparison more than justifies his prophecy, made at a meeting of the Society of Chemical Industry on March 31st, 1890, that "cyanide of potassium, hitherto used only to polish amalgamated plates, will take a front rank as chief agent in gold extraction." In 1889 the average mill contained say twenty 750 lb. stamps, and was usually located so near the neighbouring creek that the tailings from even the small amount of ore crushed up to that date had from want of fall to be periodically removed from the collecting dams and piled up in heaps. These piles of sands and slimes around the battery were regarded simply as a source of annoyance and expense, and so little was the latent wealth they contained realized that anyone desirous of removing them was welcome to do so. Owing to the scarcity of water the very turbid overflow from the tailings dam was used over and over again in the mill. The constant loss of water from soakage and evaporation was of course very heavy. The average recovery by amalgamation was 50 % to 60 %, and in addition in some few Companies concentration was practised to a limited extent by means of vanners or buddles or blankets, with subsequent treatment of the concentrates in amalating pans or by chlorination. Many Companies were without assay offices, and in fact assaying, owing to defective sampling, was not in much repute, the "pan" being usually taken as a safer guide. At this time also the enormous extent and regularity of the blanket reefs and the possibilities of profitable mining to great depths were by no means realized; many doubts were expressed as to the possibility of successfully treating unweathered pyritic ore as compared with the high-grade oxidized blanket then usually milled. This lack of confidence in the future of the fields was doubtless responsible by restricting the investment of capital for many imperfections in the equipment of the mines; and, whilst the working costs were so high and the percentage of gold in the ore actually recovered so low as compared with present figures, the average ore now milled could then only have been handled at a loss.

The first introduction of the cyanide process was made in May, 1890, at the Salisbury battery, where trials were made on parcels of tailings and concentrates for the mining Companies and the results published. The plant consisted of small vats of about 1½ tons capacity fitted with stirring gear, the charge being lowered after a certain period of agitation with 0.5 % to 2 % cyanide solution into leaching filter vats below. The precipitation of the gold was carried out as at present with zinc shavings. The incredulity with which the results claimed were first received and the classification of the MacArthur-Forrest process with other competing but now forgotten methods, were soon changed to a general acceptance of the merits of the new process.

In principle the process has remained practically unchanged to the present date, the chief advances made being mechanical devices and arrangements of plant for reducing cost of handling on a large scale, the gradual reduction of strength of working solutions combined with the adoption of leaching in place of agitation for all products through which solutions could percolate, the introduction of the decantation method of slimes treatment, the recognition of the part oxygen plays in the solution of the gold and the use of zinc couples for facilitating the precipitation of gold from weak solutions. The net result has been that the process now costs to operate hardly more pence per ton than it originally did shillings. Though gradually increasing knowledge has developed greater efficiency in all departments, yet even at the present day the saying is fully justified that a Company relies upon its battery returns for its working costs and upon its cyanide plant for its profits. Simple and generally uniform as is the composition of banket ore from a metallurgical standpoint, in that besides a minute proportion of metallic gold it is practically composed of silica and a little iron pyrites, yet the average value is so low that even with the 90% recovery from all sources now attainable, the margin between profit and loss is by no means great. Owing to the comparatively fine nature of the gold and its distribution in banket it is hardly likely that any improvements possible in amalgamation, concentration and chlorination methods would have rendered it possible to work the present grade of ore at an appreciable profit. From the imperfect fluidity of mercury the recovery by amalgamation cannot be compared with that of a liquid solvent which dissolves gold even when only partially exposed. Close concentration is costly as well as the subsequent roasting of the concentrates; it may be noted that after roasting cyaniding yields as good an ultimate extraction as chlorination though about double the time of treatment is required. Many unsuccessful attempts have been made to concentrate the gold values of the battery pulp so as to discard a worthless gangue, as is done in treating the ores of many base metals. Owing to the distribution of the gold through the quartzose as well as pyritic portion of the crushed ore these attempts have failed, with the result that as described the whole of the ore now undergoes double treatment, first by amalgamation and then by leaching.

After the period of demonstration was complete, the Robinson cyanide plant started work on a large scale at the end of December, 1890, and the results obtained therefrom and those from the Sheba plant, which began work a couple of months later, caused any lingering doubts as to the importance of the new factor in the metallurgy of gold to be dispelled. At once the erection of plants composed of square wooden vats was begun by various Companies for the treatment of their tailings heaps and the current tailings collecting in dams. The heavy cyanide consumption caused by the acid nature of this accumulated material was reduced by the use of lime. Gradually further improvements were made; large circular wooden vats were successfully constructed and used in spite of the fears expressed that on account of their large diameter the staves would collapse.

Cement vats succeeded wooden ones in some instances, but after a few years steel vats, already common in the United States, took their place. The collection by means of hoses or rotating distributors of the sands and concentrates in vats supported on masonry and provided with bottom discharge doors, instead of in dams or pits, previous to transfer to the leaching or treatment vats, was universally adopted. During all this time plants were steadily increased in size and vats of larger diameter were adopted until at the present time a 400-ton vat forty feet in diameter has become a standard size unit. Separation of the coarser and richer pyritic portion of the pulp by means of crude spitzlutte for longer treatment than the sands became common, and within the last few years the decantation process of treating the low-grade Rand slimes was developed and accepted as profitable practice. The use of lime for settling current slimes led to two unexpected advantages in amalgamation; first in allowing a prompt return to the mill of nearly all the water in the battery pulp, and secondly in improving the percentage recovery of gold on the plates. The precipitation of gold from the extremely dilute cyanide solutions used in slime treatment was first practically accomplished by the Siemens-Halske process, to be followed in turn by the lead-zinc couple, which had been originally patented by J. S. MacArthur in connection with the cyaniding of cupriferous gold ores.

Besides the direct help cyaniding has been to milling, it has materially modified the view that the percentage recovery of gold on the plates is the main point. Now the value of the residues ultimately discarded forms the criterion, and no manager hesitates to sacrifice a slight extra recovery in the mill, if reduction costs can be thereby reduced and no higher residues are ultimately discharged from the cyanide plant. In fact, the function of the mill has become that of an ore reduction machine for the subsequent operations of amalgamation and cyaniding, and questions of screens, height of discharge, ratio of water to ore are all considered in reference to their influence on the total extraction. Combined with all the main principles which have thus crystallized out have come endless improvements in detail. Cyanide bullion was at one time not worth more than £3 per ounce, but the introduction of acid treatment and manganese dioxide refining rendered any fineness desired obtainable, and of late the lead smelting of zinc gold slimes promises to supersede this on the score of economy.

The metal lead is playing an increasingly important part in the metallurgy of gold. In addition to the use of the lead-zinc couple for precipitation and lead smelting of zinc gold slimes above referred to, it is becoming the practice in some plants to add lead salts to all leaching and dissolving solutions with considerable advantage in assisting the solution of the gold and ensuring lengthy efficiency of gold precipitation by the zinc shavings from all weak solutions.

The chemistry of the cyanide process has been the subject of much research and speculation and is even now in many respects obscure. It is probable, however, that the solution of gold is really an oxidation process and its precipitation one of reduction. In the

former case some oxidizer, usually oxygen from the atmosphere, liberates nascent cyanogen which has the property of combining with metallic gold, and in the latter case nascent hydrogen, liberated by the combination of zinc with the oxygen of water, owing to oxygen having a greater affinity for zinc than for hydrogen, replaces the gold existing in the solution as potassium auro-cyanide and causes its precipitation in the metallic state.

The chief feature of Rand practice is as indicated the carrying out of comparatively cheap and simple methods on a very large scale. The bulk of the improvements resulting in reduction of working costs may be attributed to mechanical advances in plant and appliances. In fact the metallurgy of gold, like any other applied scientific process, is carried out very largely by mechanical means, and the qualifications for successful work, beyond the individuality of the operator, depend at least as much upon his acquaintance with engineering possibilities and processes as upon purely chemical or abstract knowledge. Since very large amounts of low-grade ore have to be handled at a low working cost to be profitable, complex and expensive methods whatever the ultimate extraction are impracticable, though in other countries where richer and more refractory material is handled they may be economically sound. For instance, there is no doubt that the method of treating slimes by filter-presses, as developed in Westralia, yields a considerably higher percentage extraction than is common on the Rand by decantation methods. But in Westralia the ore treated is so high grade that, in spite of the high percentage extractions obtained by filter-pressing, the slimes residues discharged after treatment frequently carry more gold per ton than does our product before any treatment at all.

Concurrent with progress in actual recovery methods sampling and assaying have been developed to a high pitch of accuracy, and every stage of the recovery work is daily checked; to such an extent is this carried that one grain of gold per ton in the cyanide solutions (or one part in fourteen millions) is determined, and a close watch even kept on the assay value of the mill water, lest it become contaminated with cyanide and consequently gold. At the same time elaborate and detailed systems of costs on each of the Companies are kept in the head offices of the mining corporations, so that by comparison any favourable results may be investigated and generally adopted when practicable, whilst any unduly high expenditure on working costs is similarly checked. The immense scale of operations renders this close attention to and watch upon details of the greatest importance, since in a modern 200-stamp mill one grain of gold or twopence per ton of ore amounts to £3,000 per annum. The "group system" renders the systematizing and comparing of results possible, whilst each department of a subsidiary Company has the assistance in any difficulty of the knowledge and experience of a consulting specialist. Another factor in the rapid development of Rand metallurgy is the fact that owing to the price of gold being fixed there is no inducement for the keeping of "trade secrets" such as exist in the metallurgy of a metal like copper, whose value depends upon

supply and demand and whose sale may be hampered by competition. The result is that a free exchange of ideas and information, much fostered by the local technical Societies and the close proximity of any mining companies to each other, exists among workers, and details of practice in any plant are open to inspection without difficulty. The workers in the metallurgy of gold being drawn from all parts of the world, conservative prejudices disappear by mental attrition amid the new surroundings and continual advances in practice, whilst advancements in knowledge elsewhere are contributed to the general stock and rapidly adopted when applicable. It is observable nowadays that many of the younger men engaging in gold extraction work are possessed of considerably more technical training than was common in the past. This tendency promises to increase and is of good augury for future progress and effective specialization. Cheap fuel and labour have been important factors of progress, and also the liberal supplies of money which investors, actuated by enlightened self-interest and with a confidence strengthened by past experience of the capacity of their technical advisers, have provided for the development and exploitation on an enormous scale of the mining properties. The actual scale of these operations is also much increased by the recognition of the fact that if a mine will supply ore for a hundred stamps for say forty years or more, it is profitable practice to put up at least double that number of stamps so as to exhaust the ore in half that time; on the ground that the ultimate profit is realized more cheaply and quickly and that the equipment of the mine will in any case be obsolete in twenty years.

In one respect these fields differ from most goldfields in other countries, which lies in the absence of customs mills or smelters. On the Rand all metallurgical as well as mining operations are carried out by each individual company, except as regards the minor matter of by-products. The absence of small private enterprises, the comparatively simple and uniform nature of the recovery work, and the adequate working capital possessed by the mining companies no doubt account for each mine having its own complete equipment.

In reference to the future it hardly seems likely that any radical changes in methods will take place. Good modern practice of wet crushing, amalgamation and subsequent cyaniding the whole of the crushed ore yields 90 % recovery on half-ounce ore at a low cost. The bulk of the gold in this remaining pennyweight is encased in the matrix and hence inaccessible to any solvent without further crushing. Whilst if reduction be carried to a sufficient degree of fineness almost 100 % recovery can be secured, the economic limit, when more gold is won than money expended in obtaining it, is at present considerably below, and likely always to be below the extractions obtainable in trials where no account is taken of cost. The scope for higher economic recovery is consequently limited to a fraction of a pennyweight per ton, and probably reduction in working costs to an equivalent value. It hardly seems probable that recovery working costs will decrease materially, any saving over present figures being off-set by an increased expenditure necessitated in obtain-

ing the small percentage additional recovery economically possible. While the extra recovery may be small measured in percentage, its absolute amount may be very large on the aggregate existing and future stamping power of these fields. But though the main lines of practice may remain unchanged there will doubtless, as in the past, be many changes in detail by process of steady growth and evolution. Among foreshadowed improvements is finer crushing before cyaniding of the coarse pyritic portion, separated by spitzlutte, of the pulp leaving the plates. This would appear more necessary the deeper the level from which the ore is mined, as such ore, possibly being more compacted from the greater pressure, seems to require finer reduction in general than ore from nearer the surface, with which in appearance and composition it otherwise corresponds. The encased gold contents of this material after cyaniding are at present considerable, the clean pyrites of course containing the most gold per ton, whilst the quartzose portion, mechanically separated, contains even a greater percentage of the gold contents of the charge.

With a more assured political future increase of leaching plant capacity is justifiable so that treatment can be continued until, on the lines of old chlorination practice, no more gold can be profitably washed out of the charge. The recent revival of schemes for the treatment of old residue dumps, and the improved results obtained since the war by the longer cyanide treatment allowed by the limited number of stamps running, have both emphasized the fact that past practice did not usually provide plants of sufficient leaching capacity.

The same reasoning applies to slimes treatment by the only process, that of decantation, hitherto demonstrated economically profitable with our low-grade product. Here extension of plant and design of future plants on a more generous scale is likewise becoming generally recognized as desirable, and the fact that with a 200-stamp mill a vat fifty feet in diameter is becoming a standard size for slime treatment indicates the scale on which this portion of the treatment is carried out. Spitzkasten were at one time in general use for thickening the slime-pulp before collection in a settling vat, but now the entire slime-pulp is run direct into collecting vats with peripheral overflow for the clear water. Possibly continuous slime treatment, using exaggerated spitzkasten in the shape of vats with steeply inclined conical bottoms, may become adopted in certain cases; it has often been discussed and experimented on and attempts are now being made to develop it on a large scale.

The treatment of drainage from residue dumps has already been referred to, and waste and surplus solutions from this and other sources as well as by-products of every kind will as time goes on be still more carefully watched and treated when of sufficient value.

There still remains one class of material on the Rand whose economic treatment is not yet possible, and this consists of the millions of tons of low-grade slimes accumulated in dams. Very appreciable profits are derived by treating current slimes of low assay value, but when slimes have once been stored the extra cost of handling, the lime required to neutralize acid compounds formed by

partial weathering of the pyrites, the difficulty of dissolving the gold owing to the lower oxygen-absorbing compounds of iron present, the extra cyanide these compounds consume, and the trouble, owing to the excess of lime salts in solution, of maintaining an efficient precipitation of the gold when it has been dissolved all combine to render the treatment of this class of material unprofitable up to the present.

The disposal of cyanide residues will as time goes on become an increasingly important problem. Improved methods are under discussion of transfer from collecting to leaching vats and of final discharge to the dumps, in which conveyor belts and mechanical vat discharging appliances play an important part and permit of relatively cheap forms of plant construction. Since labour has never been too abundant on the Witwatersrand, and its lack at the present time is more seriously felt than ever, it is probable that in the future the use of labour saving appliances such as the above will be greatly stimulated. In view of the very small percentage of the total ore available on these fields which has been crushed to date, it is doubtful whether available sites on producing properties will serve for more than a portion of future sand and slime residues, and the question of cheap removal to a distance will in time become imperative. The matter of covering the surface of the dumps with soil and cultivating suitable grasses and plants thereon—as is done to prevent the shifting of sand dunes on the French coast—has been discussed, and it would certainly be desirable to minimize the nuisance at present caused by the wind-blown sands from these deposits.

Among the desiderata of the present time is that of an improved elevator for battery pulp; tailings wheels while simple and cheap to run are costly to erect and not capable of increase when a few feet more fall is wanted; on the other hand, ordinary plunger pumps suffer terribly from wear and involve heavy maintenance charges.

There is an element of progress whose lack has often been felt by workers on these fields, and this is a metallurgical testing plant, consisting of say a 20-stamp mill and cyanide plant, with assay offices and technical laboratory attached, and with a competent staff. To make any radical change in the methods employed in a 200-stamp mill or plant is a very serious and expensive matter, and the progress of experimental work is hampered by its subordination to the carrying out of routine work, for the very natural reason that shareholders do not wish valuable and instructive information but regular monthly profits. With such an institution, supported by the Chamber of Mines and with an advisory technical board of management, experiments of great value to the mining industry could be continually carried out. New machinery and methods of handling material, and promising new processes and devices could be tested, and at the same time such an institution might serve as a reference assay office and laboratory for all Rand mining companies. Here trial crushings could be made, the value of ore samples or bullion could be determined and analyses of minerals, boiler water, coal, oil, steel, cyanide,

and innumerable other products made. Possibly with such an institution might be incorporated a physical testing laboratory.

But the dominating feature of the future will be the extent to which this already vast industry will grow. Up to the present time about eighty-five million pounds worth of gold has been produced. The greatest rate of production hitherto was during 1899 when gold was won at the rate of nineteen million pounds worth per annum. By late conservative estimates it is anticipated that in a few years twelve thousand stamps should be at work, crushing about twenty million tons of ore per annum with a gold yield valued at forty million pounds, and that this production should increase rather than decrease as time goes on. Already nearly two-thirds of the world's gold is produced within the limits of the British Empire, and for many years to come the narrow seventy mile strip of land forming the Witwatersrand proper should alone yield gold which will go far to maintain this proportion.

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#### 16.—THE SOLOR CORONA.

BY PROFESSOR J. T. MORRISON, M.A., B.Sc., F.R.S.E.

NOT PRINTED.

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## 17.—THE ELMORE ORE CONCENTRATION PROCESS.

By E. A. BLUME.

Briefly the process is:—The ore to be concentrated is crushed by means of any wet crushing mill and the resulting pulp is subjected to a process of agitation with a quantity of mineral oil. The oil has the property of attaching to itself the particles of minerals in the pulp whilst leaving the gangue untouched. The oil, carrying its load of concentrate, is then removed and the concentrate is recovered by a centrifugal machine. The process, however, has so far hardly been tried in South Africa.

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## SECTION B.

### 18.—PRESIDENTIAL ADDRESS.

By R. MARLOTH Ph.D., M.A.

#### THE HISTORICAL DEVELOPMENT OF THE GEOGRAPHICAL BOTANY OF SOUTHERN AFRICA.

Among the various branches of botanical research, which recently have received special attention, is hardly one which has developed itself more rapidly than Geographical Botany. The principal reason for this rapid growth of interest in this special study is the recognition, that the field is a much wider one than was generally thought. It appears to me therefore desirable to indicate from the outset the range of the subject as understood by modern botanists.

The various tasks, which the geographical botany of a country comprise may be arranged in three groups. The first step is the study of the distribution of the plants as we find them at present. For this purpose collections of plants have to be made in the various districts and these results have to be tabulated according to orders, genera and species, and to be compared with each other and those of other regions. The range of species, genera, orders and classes has to be ascertained, and the conclusions drawn from these observations concerning the relationship of the vegetation of the country compared with that of other regions.

Although this study will reveal many interesting facts, it cannot give us a true insight into the character of the vegetation. The next step will be the study of the societies of plants as we find them in nature. One has to examine these natural associations, which may occur in different parts of the country, not only with regard to the elements that form them, with regard to the various species that occur in them, but specially with regard to the conditions under which they exist. The influence of soil and climate, of heat and cold, of rain and drought, of light and shade, of insects and other animals, of human interference and of all other causes, which are liable to affect the life of a plant, have to be studied. When all these conditions are known, which is hardly ever the case, we shall be able to understand, why a certain plant occurs in one locality and not in another.

We shall, however, not yet know how it came there. In order to gain an insight into the life-history of a particular species of plants, it would be necessary to know something about its ancestors. In countries with younger geological formations a good deal of information of this kind has been obtained from palæontological

of South Africa and the peculiar characters of some of the more prominent plants. Whether he describes the beauty of the Acacia groves on the banks of the Gariep, the wide stretches of grassland of the Kalihari, or the barren hills of the Karroo, he does it in charming language. He notices where certain kinds of plants are common, and when and where they disappear or are displaced by others.

As an example of his style, I may quote the description which he gives of the plants which he collected when he crossed the Witsenbergen Pass for the first time:—"On the rocky summit of this mountain I found a great variety of plants, a large proportion of which I had not met with before. The beautiful nodding red flowers of *Protea nana* immediately caught my eye; and a multitude of new and interesting objects seemed as if soliciting me to admire them. I fancied they were crowding round me with complaints against the want of taste, the cold indifference towards them and the apathy which they experienced from everybody who passed their way. Some I fancied represented their having for many years produced blossoms of the most charming hues, and shed the softest perfumes without any person having deigned even to cast an eye upon them. . . . Loaded on all sides with flowers and branches of shrubs, we descended to the plain; and those who met us as we were returning to Tulbagh might have thought, as in Macbeth, that 'Birnam-wood was come to Dunsinane.'"

Not less beautiful is the account he gives of the impression which the first glimpse of the Orange River made upon him. "The first view to which I happened to turn myself, in looking up the stream, realised those ideas of elegant and classic scenery which are created in the minds of poets, those alluring fancies of a fairy tale, or the fascinating imagery of a romance. The waters of the majestic river, flowing in a broad expanse resembling a smooth translucent lake, seemed, with their gentle waves, to kiss the shore and bid farewell for ever, as they glided past in their way to the restless ocean, bearing on their limpid bosom the image of their wood-clothed banks, while the drooping willows leaned over the tide as if unwilling to lose them."

That may appear sentimental to some of us, but we must remember that he had crossed the arid regions between Karroopoort and the Gariep, and that his cattle had suffered much through want of water. On the other hand, the poet in him never interfered with his painstaking accuracy in recording every plant. It is for this reason that his *Catalogus Geographicus* has always been and is still a most valuable source of information.

Shortly after Burchell had left the Cape a new era of Cape Botany commenced, for in the next decade we find three able, enthusiastic and most energetic botanists scouring the country and collecting many thousands of plants. These three men were: Ecklon, Zeyher, and Drège.

Ecklon as well as Zeyher concentrated their energy on the collecting and distributing of plants. One of Ecklon's collections

contained 3,000 species, besides which he sent home many living succulents, bulbs, and seeds, depending for his maintenance entirely upon the proceeds of these collections.

Drège, on the other hand, undertook the work at once from a higher point of view. On his extensive travels, which took him to Namaqualand, the Orange River, the Karroo, the coast-belt, the Eastern Province, and Natal, he recorded carefully the peculiarities of each locality where he collected. As his collections were estimated to have comprised 8,000 species, represented by 200,000 specimens, it is obvious that, as Thunberg is called the father of Cape Botany, Drège is the founder of South African Geographical Botany.

In 1843 he published the results of these labours at Regensburg in a work entitled "*Zwei Pflanzen-Geographische Dokumente*," giving not only the lists of the plants collected in various parts, but also grouping them into geographical regions, which he showed on a map. Although minor modifications of some of his boundaries were found to be necessary, and although some of his regions had to be combined into larger units, the principal distinctions recognised by him were so correct and natural, that subsequent investigators could only confirm them.

Shortly afterwards a description of the forest-regions of the South Coast was given by Bunbury in the *Journal of Botany* (1843-44); while Krauss published an excellent account of the vegetation of the three main regions of South Africa in his "*Beiträge zur Kenntniss der Flora des Kap-und Natal-landes*" (Regensburg, 1846). Having explored the Southern Coast districts from Cape Town to Uitenhage, and afterwards the greater part of Natal, he describes in graphic language the contrast between the forest lands of George and the desert-like nature of the Karroo on the one hand, and the tropical character of the Natal flora on the other hand.

The botanist whose name is probably most familiar to every one who takes an interest in the vegetation of this country is Harvey, and although he did not pay special attention to phyto-geographical questions, he added many notes of this kind to the descriptions in his "*Genera of South African Plants*," and in the three volumes of the *Flora Capensis* edited under his care.

The first comprehensive description of South African vegetation from a phyto-geographical point of view was given by Grisebach in his "*Vegetation der Erde*," published in 1871. Based upon the foundations laid by Drège, Grisebach divided South Africa into three large regions. One, called the Cape region, comprised the Cape Colony south of the Orange River, the other one, called the Kalihari region, the country north of the Orange River from the West Coast to the Drakensbergen in the East, and the third one was the Southern extension of tropical Africa called the Soudan. Thus he brought down as far as the Great Fish River.

Although Grisebach's arrangements and descriptions cannot be admitted as correct in every respect, his work is a masterly account

of the vegetation of South Africa. In the 47 pages which he devotes to the Kalihari and the Cape regions, he discusses the topography of the country, the climatic conditions, the distribution of a number of orders and genera, the various forms of plant life, e.g., succulents, heath-formation, grassy plains, forests, etc., the origin of some of the larger systematic groups, the connections with other floras, and many other points. If one considers that he had to treat in this way the vegetation of the whole globe, and that he had not visited South Africa, but had to depend entirely upon the writings of others, one cannot but admire the genius who performed this task.

A different arrangement was adopted by Rehmann, who, having travelled in South Africa, and made large collections of plants, published his results in 1886 at Krakow.

One of the errors into which Grisebach was led is the view that the Orange River forms a natural boundary between the Kalihari and the Cape floras. That error was rectified by Dr. H. Bolus in a contribution to the *Journal of the Linnean Society* (vol. 14, p. 482), and more fully later on in his "Sketch of the Flora of South Africa" (1886). In this treatise, which is modestly called a sketch, the floral regions of South Africa are arranged more in accordance with Drège's original divisions and subsequent observations. It is shown that the so-called Cape flora of Grisebach consists of two, or perhaps three, quite distinct regions, and that the Orange River flows through the southern extension of the Kalihari vegetation, the portion which lies to the south of the river being known as Bushmanland. Special stress is laid upon the great difference which exists between the South Western corner of the Cape and the other portions of the country, the typical Cape flora being confined to the narrow sickle-shaped strip between the coast and the mountain ranges which form the Western and Southern boundaries of the Karroo, viz., the Cedarbergen and the Zwartebergen.

The country to the north of the Zwartebergen is divided into two regions, viz., the Karroo and the composite region, the latter comprising the Nieuwveldt and the high plains to the north of Beaufort West.

A somewhat different view of the relation of our various regions to each other is adopted by Engler in his "*Versuch einer Entwicklungsgeschichte der Pflanzenwelt*," Part II., which appeared a few years before Dr. Bolus' sketch, viz., in 1882. Engler adopts the South Western region of Bolus, and calls it the Cape flora, but all the others, inclusive of the Karroo, he finds so closely related to the large tropical and sub-tropical area of Central Africa, that he considers the Karroo simply as "the last outlayer and the poorest branch of this vast region." Some modifications of these various views are adopted by two other works on general geographical botany, viz., by Drude in his "*Handbuch der Pflanzengeographie*" (1890), and by Warming in his "*Oekologische Pflanzengeographie*" (1896). Drude combines Rehmann's and Bolus' plans, and goes even a step further by sub-dividing the latter's South Western region into two

areas. In this way he obtains seven regions, viz., the Kalahari, the Transvaal Hoogveld, the Sub-tropical Eastern Region, the Central High Veld (corresponding to Bolus' Composite Region), the Karoo, the forest districts of the coast, of which Knysna would be the centre, and the small South-Western corner extending from Mossel Bay to the Northern end of the Cedarbergen. The forest districts form a kind of intermediate zone between the sub-tropical forests of Natal and the evergreen shrubs of the Cape, many of the trees being common to both. It is in this remaining little corner of the Cape where as he expresses it, "that famous Cape vegetation asserts itself in its purest form," which is characterised by almost innumerable kinds of little shrubs and shrublets of Proteaceae, Bruniaceae, and Ericaceae, of *Phyllica*, *Geranium*, *Rhus*, and many others, and where few real trees occur, mostly in the ravines and gorges of the mountains only.

A very remarkable view of the origin of our flora is advanced by Professor H. Christ, of Basel, in his paper entitled, "*Ueber Afrikanische Bestandteile der Schweizer Flora*" (1897). He considers that at some remote period the whole or the greater part of Africa was occupied by a xerophilous flora of the nature of the present vegetation of South Africa.

"This flora is an old one, and deserves the name '*The Old African Flora*.' Its present distribution shows that it has been preserved in all those regions, where the xerophilous character of the country remained the same, while it was displaced by other elements, wherever the desert advanced, or where moist depressions favoured the development of the equatorial forest flora. The xerophilous flora is the primary one, the others are of secondary origin."

Quite a number of essays and larger works deal with various parts of South Africa. Foremost among them being the following:

Schinz: The vegetation of German South-West Africa.

Sim: Flora of Caffraria and Ferns of South Africa.

Wood: Natal plants.

Thode: Account of the coast regions of Caffraria and Natal.

Unfortunately, a few only of all these works contain any illustrations. It is, however, quite impossible for the non-botanical reader to realise the salient features of a vegetation from descriptions only. Hence it was a great step in advance when Schimper's "*Pflanzen-Geographie auf physiologischer Grundlage*" appeared in 1899, for this work is provided with a large number of illustrations of native vegetation. The chapters dealing with South Africa are unfortunately somewhat condensed, but the figures of many of our dwarf shrubs and shrublets give a very good idea of the appearance of our vegetation to the reader, who has not seen it himself.

Schimper contemplated a large increase of the South African part of his work in the second edition, and as he had visited the Cape in 1898 this revision would have been of the highest value to the student of Cape Botany. To our deep regret, however, this cannot be, for Schimper died in 1901 in the midst of his labours.

No larger contribution to the knowledge of our vegetation has been published since then, but a very interesting paper by F. C. Clarke deals with another feature of this study. In the "Proceedings of the Royal Society of Great Britain" (vol. 70) he gives an account of the distribution of the tribe Schoeneae, which forms a section of the order Cyperaceae. This account demonstrates beautifully how large the number of species of this tribe is in the Southern extremities of the three continents, and how rapidly they decrease in number further North. The obvious conclusion being, that the common origin may have been in some Antarctic region, which has either disappeared in the ocean, or is now covered by eternal ice. The importance of this paper lies in the bearing which it has on the question of the origin of this "famous flora," which predominates in the little South-Western corner of the Cape.

Let us hope that the expeditions which are at present exploring the Antartics may discover some geological records, that will throw some more light on this question.

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19.—ON THE OCCURRENCE OF AN EPIDEMIC AMONG  
THE DOMESTICATED ANIMALS IN MAURITIUS,  
IN WHICH TRYPANOSOMATA WERE FOUND IN  
THE BLOOD.

BY ALEXANDER EDINGTON, M.D., F.R.S.E., DIRECTOR OF THE  
COLONIAL BACTERIOLOGICAL INSTITUTE, CAPE COLONY.

[*ABSTRACT.*]

During the year 1902 an alarming mortality occurred in the cattle, horses, mules, donkeys, and oxen in Mauritius.

Drs. Lesur and Lorans, after finding Trypanosomes in the blood judged it to be Surra, and, as some Indian bullocks had been recently imported, it was believed that the malady had been brought with them.

The Governor of the Island having applied to the Governor of the Cape for my services, I arrived there in July.

Investigation then made showed me that not only had the disease been existent on the Island previous to the arrival of the Indian bullocks, but that these animals themselves died of it.

The Trypanosomes found in the blood are about 15 microns in length. One end is somewhat blunt, while the other is long, tapering, and ends in a long flagellum. Along one side there runs a wavy membrane, which is attached near the blunt extremity and extends to the tapering end.

Near the blunt end there is a small spot, which stains red with the Romanowsky method. Nearer the centre, or just behind this spot, there is a larger spherical clear spot, which may be regarded as a vacuole. In some this vacuole is not visible, but in such there is a second small spot staining brightly, and situated just behind the other one. This may be either a stage of division, or may be a sexual characteristic.

The protoplasm, about the centre of the parasite, is somewhat condensed, but does not take on the red staining.

Movement is effected by the flagellum, by a vermicular movement of the parasite's body and by the wavy motion of the undulating membrane.

Transmission of the disease is effected by a fly, which is somewhat like the ordinary house fly, but is called there the *mouche-boeuf*. It is believed to be a variety of *Stomoxys*.

I believe, however, that there are other methods of transmission, and, in particular, I cannot overlook the fact that animals live near the docks, where the fly also is found, whereas the infection is greatest in marshy areas.

The disease has been produced experimentally in the Bacteriological Institute.

Young cattle withstand huge doses, and while the parasites appear in the blood the animals many months later are still in good health.

A pig has entirely resisted inoculation.

Two goats were inoculated with large doses without showing infection of the blood microscopically, nevertheless, the blood of these goats served to produce the disease in clean dogs inoculated with it.

Pigeons entirely resist infection.

Guinea-pigs shew great differences in resistance, some dying after a few weeks, others living for months.

Rabbits behave somewhat similarly, but death is almost certain to occur in these animals with great emaciation shewing itself previously, and in many cases a progressive panophthalmitis is found.

In horses, dogs and rats and mice the malady runs a very acute course. Horses which have been "salted" to horsesickness are as susceptible as clean horses. From the point of view of its infectiveness it is not yet clear that its affinities are either with the Tsetse parasite or the Surra.

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20.—NOTE ON THE CO-RELATION OF SEVERAL DISEASES OCCURRING AMONG ANIMALS IN SOUTH AFRICA.

BY ALEXANDER EDINGTON, M.D., F.R.S.E., DIRECTOR OF THE COLONIAL BACTERIOLOGICAL INSTITUTE, CAPE COLONY.

In South Africa one finds quite a number of ailments occurring in the domesticated animals and, while the onset, symptoms and morbid anatomy of those affected shew the ailments to be peculiar to Africa, the names given to the maladies are unknown in any other country.

Horses and mules are liable to the enormously fatal malady known as Horse-sickness.

The mode of onset, symptoms and morbid anatomy of this disease have been already fully described.\*

High-bred goats and sheep are exceedingly liable, in certain areas of Cape Colony, to a disease known as Heart-water. The areas within which this disease exists begin at the coast in the Eastern Province and extend inland irregularly for some distance.

In the animals which die of this disease it is common to find a considerable quantity of pale yellow serous effusion in the pericardium.

The epi. myo and endocardium commonly shew little or no departure from the normal.

The pleural cavity may contain some yellow serous fluid or may be empty.

The lungs may be almost normal or there may be some exudation found into the interlobular tissue.

While the lungs as a whole may be quite pale in colour there may be found irregular sharply defined chocolate-coloured patches of congestion.

There may also be found more or less of gastro-enteritis and, in cases running to the full term, the gall bladder may be distended with more or less inspissated bile which, while usually of a deep bottle green, may be sometimes brown in colour.

The incubation period after the intravenous inoculation of a clean goat with 5 c.c. to 30 c.c. of the blood of an animal dying of the malady is as a rule about ten days. This period, however, may be greatly diminished or extended; from a few days up to nearly three weeks in some cases.

From the point of view of experimental infection the results, which I have obtained from experiments conducted on nearly five hundred goats, are paradoxical in the extreme.

When I first began my investigations I used goats which were born and reared on a farm, near Grahamstown, which was believed to be outside of the area infested with the disease.

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\* Vide reports of the Director of the Bacteriological Institute.

On infested farms the mortality during the summer season is very high, but no unnatural mortality had occurred on this farm during the past ten years at least.

The material used for purposes of infection was the blood taken from animals dying of the disease at Koonap and at Somerset East. The blood was either simply defibrinated or mixed with a small quantity of a solution of neutral citrate of potash. I was unable to find that either had any advantage over the other as an infecting agent.

Subcutaneous injection of doses as large as 40 c.c. almost always failed to produce death, although some oscillation of the temperature of the inoculated animals was observed.

Intravenous inoculations of doses up to 30 c.c. were uncertain.

Where the animals inoculated in this way developed the disease and died, there was no certainty that their blood would produce the virulent disease in others. Failures have occurred even with the injection of 100 c.c. into the jugular vein.

In some cases blood which was drawn from inoculated animals, which did not themselves die, proved capable of setting up the virulent disease in others.

As further indicating the paradoxical nature of the malady I may add that in by far the greater number of these goats which had resisted inoculation it was proved that an inoculation of even a much smaller dose of blood at a later date or exposure of the animals in an infested veld was attended with the production of the malady followed by death.

I felt, therefore, that these goats, which largely resisted infection, although being not immune, had acquired what one might term a modified resistance or acclimatization.

This is the more probable from the following circumstance. Mr. Thomas Hoole, a well-known breeder at Highlands, made a purchase of a considerable number of goats from a district of Somerset where the disease is known to be absent. After purchasing he sold part to Mr. L. White, whose farm lies many miles distant. After these goats had been placed on the respective farms they began to die of Heart-water, while contrarily the animals belonging to the place did not die. On both farms Heart-water occurs.

I may further add that the ordinary Boer goat is practically insusceptible to the malady, and that the pure bred Persian goats possess a high degree of insusceptibility to natural infection.

In some parts where the disease only occurs to a slight extent I have had it reported to me by the farmer as being Gall-sickness, thus called as the gall bladder is often very much distended with bile.

Since that time I have imported all goats by train from a clean area in Somerset and in these animals I have found it much easier to keep up a strain of infection from animal to animal.

Still, however, inoculation frequently fails and I felt constrained to report to my Government that goats evidently were not the proper animal host for the contagium of this malady.

In sheep the conditions are practically the same.

In cattle a number of names are applied to diseases by the farmers, which have given me immense trouble in the attempt to identify. The names with which I shall now deal are:

1. Imapunga (Kafir: "Lung").
2. Boschziekte (Bush sickness).
3. Gall-sickness.
4. Veld-sickness.
5. Black Lung-sickness.
6. Rivierziekte (River sickness).

There is no official work which enables anyone to identify the maladies above named but, since, my own work has been completed, I have obtained, a few weeks ago, a copy of the "Report of the Commission appointed to enquire into Disease in Cattle in the Colony," dated 1877.

Among the numerous minutes of evidence I desire in particular to refer to the very valuable and strikingly accurate observations of the late Mr. J. Webb, who owned then a farm near Grahamstown, consisting of sour veld as contrasted with the sweet veld of the Karroo.

"Question 2705. Have you noticed any change in the veld during the last few years?"

Yes, stock of all kinds have been doing badly and sheep and goats it is now impossible to keep on farms which at one time were considered to be the best grazing farms in this neighbourhood.

2706. What do you think is the cause of it?

My opinion is we have a tick which made its appearance in the last 8 or 9 years. I suffered from them then, a bontetick, small like a ladybird. I was farming on a farm without ticks; directly this tick appeared all my stock did badly, calves died of gall-sickness, bosch-sickness, one man lost 2,000 or 3,000 sheep and goats; I believe the tick caused it. I have also shot bush bucks suffering from the same causes, this was at Southey's Poort, Fish River. As this tick increases so diseases increase, for wherever the tick is found there are the same diseases; the tick has now travelled over 60 miles.

2710. Did you open and examine them?—A few sheep, not often.

2711. What did you notice?—The Heart bag and chest full of water.

2716. You have had large experience in cattle?—Yes.

2717. What do they die of?—Below Grahamstown of Gall-sickness. North very few die compared to the south. We have three sicknesses here called by the farmers: Gall-sickness, bosch-sickness, and sweet veld-sickness; I believe they are all the same."

It is generally known to farmers that if Karoo cattle are brought down to the coast areas of the Eastern Province the greater number will die.

For re-stocking the northern territories large numbers of cattle have been bought, of which great part are Karoo animals. Of these many have been grazing on the same farm which Mr. Webb spoke of, and of the Karoo cattle a very large number are already dead.

## HORSE-SICKNESS CO-RELATED TO VELD-SICKNESS.

During the earlier part of my work in this Colony I endeavoured without success to transfer the disease known as Horse-sickness from the horse to cattle.

The cattle used in these experiments were of the class known as Zuurveld cattle.

It has been known during several generations of farmers that if cattle living in sweet veld areas are brought to zuurveld areas they are exceedingly liable to die very soon after their arrival.

Owing to this the Zuurveld cattle, sold on the Grahamstown market, fetch higher prices than those from sweet veld and, indeed, most farmers, in this area, refuse to purchase sweet veld cattle at any price owing to the area being a Zuurveld one.

If then sweet veld cattle die when transferred to sour veld, what is the nature of the disease produced in them?

After inoculation for Rinderpest had been well advanced in the Eastern Province, it was found necessary to be exceedingly careful of the kind of animals, used to produce virulent blood, and a large number of animals were conveyed from sweet veld areas to a camp at Waai Nek, about two miles from this Institute.

Of these considerable numbers died, but the cause of their death was not understood and the enormous pressure of work connected with Rinderpest prevented definite investigations being taken up for this purpose and we had to content ourselves with attempting, by treatment, to save as many as possible.

Most of the deaths were reported to me by Mr. Robertson as belonging to Steynsburg cattle and he emphasized the fact of their being sweet veld cattle while our veld was zuurveld.

While this condition of things was in progress, a Bechuana boy (a herd brought from Taungs who had worked with me there) living at the camp, came in and reported to my veterinary assistant, Mr. William Robertson, M.R.C.V.S. (now assistant to the Colonial Veterinary Surgeon) that one of the cows had died of "Paardeziekte." As a result of this report Mr. Robertson rode to the camp and returning almost immediately stated to me that an animal had just died and that it had a cloud of white foam lying around the nostrils and mouth.

I immediately proceeded with him to the camp and saw the animal lying dead. It had a large quantity of white foam lying around the nose and mouth exactly as one sees so frequently in the cases of horses which have died of Horse-sickness.

On making a post-mortem examination the similarity to Horse-sickness was extended since we found the following conditions.

The lungs shewed an exceedingly well-marked interlobular exudation of yellow serous exudation. This was so characteristic, that, had the lungs only been shewn to me, I should have believed they had been taken from a horse that had died from Horse-sickness. In another case of the same sort which had been dead some hours before

the post-mortem examination was made, there was in addition some emphysema of the apices and free edges of the lungs.

The pericardium contained an excessive amount of yellow serous fluid.

No abnormal condition was seen in the abdominal cavity except the spleens which were slightly enlarged, the liver which was in both cases congested and friable, and some exudation of serous material into the omentum and mesentery.

No micro-organisms of any kind were found in the blood.

This occurrence was somewhat surprising to us both and I thereupon determined upon attempting once more the infection of clean cattle with Horse-sickness from the horse.

Accordingly I took several animals of a new consignment to the Institute and then under careful conditions carried out the experiments.

On the 4th February 1898. Mr. Robertson and I inoculated a clean young ox with 30 c.c. of fresh Horse-sickness blood which we injected into the jugular vein. Some reaction occurred during the first few days after which the temperature fell, but on the 16th day it rose. The maxima were as follows till the moment of death.

16th day	...	...	...	...	106.4
17th	..	...	...	...	106.6
18th	..	...	...	...	107.0
19th	..	...	...	...	107.2
20th	..	...	...	...	106.2
21st	..	...	...	...	died.

"The post-mortem was of interest inasmuch as nearly every symptom of Horse-sickness was reproduced, the interlobular pulmonary effusion, the pleural and pericardial effusions." (Vide Report of the Director of the Colonial Bacteriological Institute for the Year 1898.)

Ten c.c. of the blood of this ox was used to inoculate by subcutaneous injection, horse No. 122. After an incubation period of eight days, the temperature rose, and the animal died, on the 13th day, of typical Horse-sickness.

Ten c.c. of the blood of this ox was also used, by intravenous injection, to inoculate a second ox, in which the temperature rose to 106.4 on the 11th day, to 107.4 on the 12th, and which we killed when dying of the disease on the 16th day.

At that time, having succeeded so completely in transferring the disease to cattle, I tried also to infect goats.

The goats, however, were born in this area, and are more insusceptible than goats taken from other areas.

Of the several goats inoculated none died, but most had severe reactions.

One of these goats, which had been inoculated with 10 c.c., subcutaneously, of preserved horse-sickness blood, and developed a high temperature as a result, was bled on the 10th day after inoculation.

A young ox was inoculated with 30 c.c. of this blood by intravenous inoculation on the 18th February, 1898.

During the first few days the temperature was irregular, and then took a normal course, but thereafter the following temperatures were recorded:—

10th day	...	...	...	...	104'6
11th	"	...	...	...	106'6
12th	"	...	...	...	106'6
13th	"	...	...	...	107'0
14th	"	...	...	...	107'4
15th	"	...	...	...	107'4
16th	"	...	...	...	105'4
17th	"	...	...	...	96'8 Death.

In this case the post-mortem examination showed very well-marked symptoms of Heart-water.

These experiments therefore showed:—

1. In a most definite fashion, that cattle from sweet veld areas are more or less susceptible to Horse-sickness.

2. That the disease so produced was indistinguishable from that which had occurred spontaneously in our camp.

Still, however, I was unable to identify the disease, although I learned that it was well known to the Kafirs under the name of Imapunga.

Shortly after this a number of deaths were occurring among young calves on the farm of Mr. Hyde, and Mr. Robertson and I, who proceeded there, obtained a post-mortem examination which enabled us to determine that it was the same disease which we had already seen in our camp.

During the past two years a very large mortality has occurred, among calves, from this disease, but it is to be remarked that the old animals are either insusceptible or well protected, since very few of the old animals which have been accustomed to the veld die of it.

In the case of animals, however, which are brought from sweet veld areas, it is the rule rather than the exception for them all to die.

I have had to import a considerable number of calves from other areas for use in the Institute, and among these a fairly heavy mortality has occurred from this cause.

During the war a large number of fine trek oxen were sent to Grahamstown by the Military Authorities, and to the best of my knowledge almost all of these coming from De Aar, Naauwpoort, and Cradock died. The following will show the results in two lots coming, respectively, from Naauwpoort and Cradock:—

1. Oxen from Naauwpoort (16) which arrived at Grahamstown on the 23rd August, 1901:—

- \* 1 died on September 25th.
- 1 died on September 27th.
- 1 died on October 3rd.
- 1 died on October 8th.
- 1 died on November 15th.
- 1 died on November 24th

2. Oxen from Cradock (14) arrived at Grahamstown on December 2nd, 1901:—

- 1 died on 24th December.
- 1 died on the 25th December.
- 1 died on the 30th December.
- 1 died on the 2nd January, 1902.
- 1 died on the 3rd January, 1902.
- 1 died on the 7th January, 1902.
- 1 died on the 11th January, 1902.
- 12 died on the 12th January, 1902.
- 1 died on the 13th January, 1902.

I had an opportunity of examining some of these animals, and was able to determine the identity of this disease with that which I had formerly seen occurring spontaneously, and with that which I had produced by the inoculation of clean animals with Horse-sickness blood.

While the Kafirs call this by the term Imapunga, I have found, by consulting transport riders whose experience extended over many years, that this disease is known to them under the name of Veld-sickness, or Veldziekte.

The principal lesion is an exudation of a yellow serous fluid into the following structures:—

1. Subcutaneous, in and along the lines of the intermuscular fasciae.

2. Sometimes, but not always, in the pleural cavity.

3. Commonly into the interlobular tissue of the lungs. Sometimes it is present to an exceedingly light degree here, and it is necessary to examine carefully to determine where the normal becomes abnormal since the interlobular tissue in ruminants is more than in the equids. In very many cases, however, one finds the interlobular infiltration forming bands from one-eighth to a quarter of an inch in thickness.

4. Into the pericardium. The amount found in this situation varies within wide limits; in some cases it is but little in excess, while in others the pericardial sac is filled. A variation is to be found also in Horse-sickness. I have found in some horses only a few ounces of fluid, while in others more than half a gallon was found in the sac.

5. Around the base of the heart.

6. In the anterior mediastinum.

7. Between the lower border of the pleura and the diaphragm.

I have several times found the exudation here to form a solidified layer nearly half an inch in thickness.

8. Into the tissue of the omentum and mesentery.

9. Into the submucosa of the intestines.

Secondary lesions:—

1. Collapse of lobules of the lung, with a corresponding traumatic emphysema of the adjoining lobules.

2. In cases which live for a day or two longer than the more highly susceptible animals it is common to find congested lobules of a dark, almost black colour. These lobules are sharply defined from those immediately adjoining, and from their somewhat superficial resemblance to the appearance seen in Pleuro-pneumonia, such cases are called by the farmers Black Lung-sickness.

3. In some cases one finds extravasations of blood below the endocardium of the left ventricle, especially in relation to the attachment of the chordae tendineae.

4. The liver is commonly congested and enlarged, and, in the last stages, the gall bladder is distended. The bile is of a deep green colour as a rule, but in some cases is brown. When the quantity of bile is very small, it may be of a somewhat syrupy consistence, but never shows the peculiar tenacious mucous character so well known in Texas Fever.

5. The small stomach is frequently the seat of patches of congestion, more or less of a red colour, which may even have gone on to active inflammation.

6. The conditions seen in the stomach may be found frequently in the intestines, and a general gastro-enteritis may even be set up.

7. The spleen may be slightly enlarged, but is firm in consistence. The malpighian bodies are more prominent than in the normal condition.

8. A slight amount of yellow serous exudation may be found sometimes in the pelvis of the kidney; otherwise the organ is normal.

9. In even the best marked cases the urine and the bladder are commonly absolutely normal.

10. In cases which have been dead for some time and exposed to a hot sun there may be some patches of emphysema in the lungs.

On examination of the blood and of smears from the kidneys and liver no micro-organisms are to be found except in animals which have been dead for some hours, when a large putrefactive bacillus is frequently to be found.

The blood is always of a good colour, and the rapidity of coagulation is always increased.

The fever in these cases is commonly very high. A remarkable feature in the malady is the fact that animals may seem in perfect health, yet when the temperature is taken it may be found to be over 106 F.

It is common to find animals showing symptoms of illness only a few hours before death.

As this disease is well defined in cattle, and runs on parallel lines with Horse-sickness in horses, I suggest that it should be denominated "South African Cattle-sickness."

While the blood of the first ox proved virulent to an ox, I found after three transferences through oxen that it becomes relatively virulent to the ox, but may fail to produce virulent disease in the horse even when used in the fresh state.

## HEART-WATER.

In my Annual Report for 1896, observations were made which at a later date were communicated to the Royal Society (Vol. 65) showing that the germs of Red-water or Texas Fever may remain latent in the blood of cattle for long periods of time after their recovery from an attack of the malady, and that cattle born on Red-water veld, although they may not have been affected by this malady, yet can, and do carry infection, in a latent form, in their blood.

During my investigations into Heart-water I began to have suspicions that something of the same nature was concerned in regard to the latter malady.

The following experiments shew in how far these suspicions were verified:—

*Experiment 1.*—To prove that the contagium of Heart-water may be communicated to a susceptible animal in a non-virulent form and passed in succession through several others, eventually being raised to full virulence in the passage.

I obtained a number of clean goats by train from a clean area, and enclosed them in a courtyard, which, in turn, was bounded by stone walls.

Along one side of this yard galvanised iron enclosures were erected, into which the animals were placed while under experiment. The most rigorous care was exercised in regard to cleanliness of the place, each shed being at frequent intervals thoroughly cleaned and disinfected.

While I have found that Horse-sickness blood can be preserved by the addition of an equal volume of glycerine and water containing 1 per 1,000 of Phenol, so that it retains its virulence for at least three years, the blood of goats dying of Heart-water when so treated loses its virulence in a few days. Such preserved blood does, however, almost always set up a slight oscillation of the temperature in animals inoculated with it.

Goat No. 252 was inoculated with 10 c.c. of glycerinated blood taken from an animal which had died of Heart-water. The injection of this material was made subcutaneously on September 5th, 1901.

No febrile change was observed until the 21st September. On this day the temperature rose to 107°F. in the middle of the day, but regained the normal on the following day.

Goat No. 258 was now inoculated with 100 c.c. of the blood of No. 252.

Some irregularity of temperature was produced, but no very definite reaction, and on the 9th October (being the fourteenth day after inoculation) it was bled, and Goat 265 was inoculated subcutaneously with 100 c.c. of its blood, and with 25 c.c. injected into the jugular vein.

On the following day there was a sudden elevation of temperature to 106'4, and on the fifth day the animal died of characteristic Heart-water.

The two previously inoculated animals remained meanwhile in seemingly good health.

*Experiment 2.*—To prove that Goats Nos. 252 and 265, through which the virus had been transmitted while in a non-virulent form, were in no degree protected thereby against subsequent inoculation with virulent virus.

Goat No. 266 was inoculated on October 10th with 100 c.c. of the blood of 265 by subcutaneous injection and with 20 c.c. injected intravenously.

On the 8th day the temperature ran up to 105°4.

On the 11th day the temperature ran up to 104°8.

On the 12th day the temperature ran up to 106°4.

On the 13th day the temperature ran up to 104°4, when it died of Heart-water.

NOTE.—During the progress of these experiments clean goats were always kept with the experimental ones, and at the close of the experiments they were all inoculated with virulent blood, and all died of Heart-water.)

Goat No. 252, which had been inoculated as already seen with non-virulent blood, was now inoculated on the 23rd October with 30 c.c. of the blood of No. 266 by intravenous injection.

On the 6th day the temperature rose to 104°4.

On the 7th day the temperature rose to 107°6.

On the 8th day the temperature rose to 107°4.

On the 9th day the temperature rose to 106°6, when it died of typical Heart-water.

Goat No. 258, which also had been already inoculated 28 days previously with non-virulent blood, was now inoculated on October 23rd with 30 c.c. of the blood of 266 by intravenous injection.

On the 7th day the temperature rose to 107°4.

On the 8th day the temperature rose to 103°6, when the animal died of typical Heart-water.

Goats Nos. 278 and 279 were each inoculated in the same manner as controls, and in both cases the temperature began to rise on the 8th day afterward, and death occurred on the 11th.

In the above experiment, therefore, it is seen that the virus, which had originally passed through Goats Nos. 252 and 258, and was by that means raised to virulence, actually killed these animals when re-inoculated into them after its accession to virulence had been achieved.

Hence Heart-water virus of which the virulence has been lowered does not necessarily afford protection to animals which have been inoculated with it.

*Experiment 3.*—To prove, in such cases as those of animals Nos. 252 and 258, that an inoculation with weakened virus actually predisposes to subsequent infection with virulent blood.

In both of the above cases it is to be noticed that the incubation period was shortened as compared with the "control" animals, and I have further to add that this observation has been abundantly confirmed in a vast number of other cases.

### TRANSMISSION OF HEART-WATER FROM GOATS TO CATTLE.

A clean ox from a sweet veld area was inoculated by the injection of 5 c.c. subcutaneously and 5 c.c. intravenously of blood from a goat which was dying of Heart-water.

On the 15th day after inoculation the temperature began to rise, reaching during the evening to 106.4. During the five days subsequent it was maintained about 105F. without remission, but the following morning it fell to 101.8, and on the same evening ascended to 107.2. It died two days later.

On making a post-mortem examination, I found the pericardium filled with fluid. There was some interlobular pulmonary infiltration, and indeed there were produced conditions similar to those we are accustomed to find in goats dying of Heart-water.

On the 16th day of the disease it was bled, and after defibrination of the blood a goat was inoculated by the injection of 10 c.c. subcutaneously and 10 c.c. intravenously.

This goat died seventeen days later of typical Heart-water.

The type of fever induced in cattle by the inoculation of Horse-sickness blood is practically the same as that obtained by the inoculation of the same species of animal with Heart-water blood.

The post-mortem conditions are likewise identical, and agree in all particulars with those found in the endemic disease occurring in cattle, and known to the Kafirs as Impunga, while having shown typical cases to experienced transport riders they have assured me that it is known to them as Veld-sickness.

As I have already said, Karoo cattle coming to the coast areas are liable to become attacked, the coast cattle remaining in perfect health.

Transport riders assure me that cattle from these coast areas can travel throughout the whole of South Africa, except in the Tsetse Fly belts.

I have ascertained that this disease occurs on the velds on which Heart-water is known to exist.

### THE CO-RELATION OF VELD-SICKNESS AND HEART-WATER.

*Experiment 5.*—To determine the relation of Impunga or Veld-sickness in cattle to Heart-water in goats.

With blood taken from a Graaff-Reinet calf dying of Veld-sickness I inoculated Goat No. 312 on December 16th by the intravenous injection of 30 c.c. of the blood.

The temperature began to rise on the 5th day, and the animal died on the 15th day of Heart-water.

The post-mortem conditions were absolutely typical of Heart-water occurring spontaneously among goats.

Goat No. 327 was inoculated in the same manner with the blood of Goat 312 on December 30th, and died on the 17th day of Heart-water.

Goat 331 was inoculated in the same manner with the blood of 327, and died on the 15th day with similar symptoms.

I could not detect the slightest difference between those cases and cases of Heart-water produced either spontaneously or by inoculation.

*Experiment 6.*—To show that goats born and reared on a farm infected with Veld-sickness are not so susceptible to that disease as are goats which have been reared on a clean veld.

Goat No. 305 from a farm on which Veld-sickness exists was inoculated on the 24th November by intravenous injection of 20 c.c. of the blood from a calf which had died of Veld-sickness. A slight reaction followed immediately, and soon subsided.

On the 12th January it received intravenously 30 c.c. of the blood of 327 at the same time as No. 331 of the previous experiment.

While this goat remained unaffected the clean goat No. 331 died.

*Experiment 7.*—To show that goats reared on a farm infested with Veld-sickness are relatively insusceptible but not immune.

Goat No. 315 from a Veld-sickness infected farm was inoculated on the 14th December with 10 c.c. injected subcutaneously and 10 c.c. intravenously of the blood of a calf which died of Veld-sickness.

A slight febrile reaction of short duration followed. On the 12th January it received 30 c.c. intravenously of the blood of No. 327, and as a result died of the disease on the 13th day. (This result is in agreement with what we find obtaining among goats running on a Heart-water veld when these are inoculated with Heart-water.)

*Experimental Observation 8.*—To show that goats reared and running on a farm infested with Veldziekte are relatively insusceptible to Heart-water.

In my prefatory remarks I alluded to the fact that goats purchased on the farm of Mr. G. Palmer (which is a Veld-sickness infested farm) were relatively insusceptible to Heartwater but not immune, since although they very frequently resisted the intravenous injection of Heart-water blood, yet if a second inoculation was made at a later date they commonly succumbed.

*Experiment 9.*—To prove that goats relatively insusceptible are not actually immune.

In almost every case where one of the goats from Mr. Palmer's farm, inoculated with virulent blood either from Somerset Station, Koonap, or that obtained by me from experimental goats, have withstood the intravenous injection of virulent blood I have found:—

1. That they have been actually infected, although showing no signs of disease, since with their blood I have been able to infect

susceptible goats, which in some cases have died of the virulent malady.

2. That if, after unsuccessful inoculation, they are allowed to remain in the Institute for several weeks, a subsequent intravenous inoculation of virulent blood is almost always successful in producing the disease and death.

*Experimental Observation 10.*—To show that goats on farms in this and adjoining areas, reared and living there, are relatively insusceptible.

I have already referred to the experiences of Messrs. Hoole and White, which suffices as evidence in this respect.

#### CO-RELATION OF HORSE SICKNESS TO HEART-WATER, TO VELD-SICKNESS IN CATTLE, AND TO A CONDI- TION KNOWN AS VELD-SICKNESS IN HORSES.

If horses which have been reared in the Karoo are brought down to the coast areas it is usual to find that they fall off in condition, and in some cases die. From what I have heard and seen I am constrained to believe that this condition is that which was referred to in the report of Lieutenant-Colonel Joshua Nunn, F.R.C.V.S., A.V.D., to the Director-General of the Veterinary Department of H.M. War Office in 1888, as the Biliary form of Horse-sickness. Among the farmers it is, however, commonly referred to as Veld-sickness.

In my communication to the Royal Society (Vol. 67), I referred to the results which I had obtained by the inoculation of donkeys with the blood of animals dying of Horse-sickness, and thereafter using the donkey's blood for the inoculation of horses.

Since that communication was made I have been able to extend experiments of that class, and the results may be summarised as follows:—

1. The reaction produced in the donkey is no guide to the result which may follow the inoculation of its blood into a clean horse. The reaction may be slight or may be fatal.

2. If the donkey's blood is drawn at the tenth day and used to produce in a clean horse a violent reaction, then the blood of the same donkey, if drawn two or three days later (without any further re-inoculation) will cause a much more violent reaction, and possibly death from virulent Horse-sickness.

3. If a mild reaction is produced it may be of the nature of high temperature with remissions, or if still milder may have a lower degree of fever with long intermissions.

In the case of animals which suffered from the last form of fever it was always noticed that they fell off in condition to a remarkable extent, becoming mere skeletons.

If killed or dying as late as the 50th day one found evidence of Horse-sickness in the form of exudation of serous material into the subcutaneous tissues, the interlobular tissue of the lungs, into

the mesentery, the pleural cavity, and sometimes into the peritoneum. In the interventricular groove of the heart one always found some serous exudation, and the vessels lying here were always opaque owing to an infiltration into the vascular coats.

The condition might be regarded as a sort of chronic Horse-sickness.

The inoculation of 10 c.c. of Heart-water blood into a clean horse produced similar phenomena, the animal dying two months after inoculation.

I have only made a few inoculations with Heart-water into horses, and in some cases even a large dose (50 c.c.) has only produced a transient febrile reaction.

During the war camps were formed for the receipt of farmers' horses, and reports reached me that horses running in some of these camps were dying in large numbers from "poverty," "scab," etc., and as these camps are infested with Veld-sickness it seemed to me that probably they were suffering from the "chronic form of Horse sickness," which I had experimentally produced.

On the 29th December I proceeded to the protection camp at Thorn Park in this district, accompanied by the local officers, Mr. E. White and Mr. Dalton. I saw no dead animals, as these had been already buried, and therefore decided to shoot anyone which I might see in a poor condition. After several hundreds had galloped by, I determined upon one which seemed poor enough, although it galloped quite freely. One of the officers then managed to bring it down with a rifle shot, and we at once proceeded to make a post-mortem examination.

1. The subcutaneous tissue was not invaded to any definite degree by exudation, although along the lines of the great vessels in the neck there was evidence that it had existed, but had coagulated, and was now in process of absorption, leaving tough lines of dry exudation.

2. The pleural cavity contained about one gallon of a clear yellow serous fluid.

3. The lungs showed patches of congestion, some of which were deep, liver-coloured. There was a definite amount of subpleural infiltration of serous fluid. There was also a widespread condition of interlobular infiltration of serous exudation.

4. The pericardium, or heart-sac, contained about 40 ounces of clear yellow or straw-coloured serous fluid and some masses of coagulated gelatinous material produced by the coagulation of the fluid.

5. The base of the heart was surrounded by a huge gelatinous mass, and the interventricular groove was filled up by the same material.

6. The aorta and the larger vessels of the interventricular groove were invaded by the exudation, and the latter were rendered absolutely opaque, looking like white clay-pipe stems lying in a jelly.

7. Some fluid was also found in the peritoneal cavity, but no other characteristic pathological lesion was found.

Two days later, Mr. Dalton proceeded to another camp, and, having shot a horse there, brought to me the heart and lungs "en masse."

The conditions found here were identical with the foregoing case, but rather more aggravated in type.

I cannot regard these and similar observations which I have made otherwise than as indicating that the condition which I produced in clean horses by Heart-water blood inoculation and also by the injection of the blood of Horse-sickness inoculated donkeys is of the same nature as that which existed among the horses of the protection camps.

In cases where I carried my experimental inoculations so far as to produce perfect protection against Horse-sickness, the animals immediately thereafter began to put on flesh.

#### TRANSMISSION OF HORSE-SICKNESS FROM HORSES TO GOATS.

As I have already said, the inoculation of even a large dose of Heart-water blood into a horse may fail to be attended with any very definite result.

Conversely, the inoculation of Horse-sickness blood into goats was attended with uncertain results. In my first experiments, out of seventeen inoculated at different times, a febrile reaction occurred in only ten, and none died. These goats, however, were obtained from Mr. Palmer's farm.

Since then I have used absolutely clean goats, and have had further success.

On the 7th March, 1893, I inoculated goat No. 381 with 20 c.c. of fresh Horse-sickness blood by intravenous injection. It died three days later.

On post-mortem examination I found an enormous interlobular exudation into the lungs and pericardium. In the latter the whole exudation was absolutely solid.

This remarkable result is somewhat to be compared with experiments which I made a few years ago in inoculating a goat and a sheep with the serum of a "salted" goat which had been re-infected by inoculation a week previously.

The sheep and goat were inoculated in the forenoon, and were found dead the next morning with symptoms very similar to those just recorded.

With the blood of Goat No. 381 I now inoculated No. 383 by intravenous injection of 5 c.c. of defibrinated blood on the 9th March.

Some fever followed, and on the 10th day it had a temperature of 106, making, however, a good recovery.

On the 20th March I bled this goat, and inoculated No. 393 with 5 c.c. by intravenous injection.

After an incubation period of six days the temperature began to rise, and the animal died on the 16th day. On making a post-mortem examination I found the usual signs of Heart-water.

No. 393 was used to inoculate No. 408, which died on the 14th day.

No. 408 was used to inoculate No. 411, which died on the 13th day.

No. 411 was used to inoculate No. 419, which died on the 11th day.

This experiment, which has been carried out with every care as regards the keeping of control animals in contact during the experiment, and subsequently showing by inoculation that the controls were still susceptible to virulent infection, admits me to say that Horse-sickness can be transferred to goats, and that, when acclimatised to the goat, it produces in this animal a virulent disease, which is indistinguishable from the endemic disease of goats, which is known in South Africa as Heart-water.

#### HEART-WATER PRODUCED BY THE INOCULATION OF THE BLOOD OF PROTECTION CAMP HORSES.

I was enabled to get a protection camp horse sent into the Institute, and while there I bled it, and inoculated Goat No. 356 with 30 c.c. intravenously and 30 c.c. subcutaneously on the 11th February.

On the 7th day the temperature rose, and remained high, 105F. and slightly over, until the 11th day, when it fell to 101, and the animal then died.

On making a post-mortem examination I found oedema at the base of the heart of a semi-transparent character, extending up to the aorta. The lungs were pale, but the left had a dark patch of congestion about two inches in diameter, and being sharply circumscribed within a group of lobules. The pericardium was quite filled with a clear yellow serous fluid, which quickly coagulated when transferred to a glass. The conditions found were thus absolutely typical of what one obtains in ordinary Heart-water.

I therefore conclude that the contagium which causes Horse-sickness in the Equids of South Africa is responsible, under conditions of relative virulence, for the infection of other species of the domesticated animals.

The means by which the virulence becomes relatively altered is not entirely clear, but my colleague the Colonial Entomologist has been able to produce Heart-water in goats and calves at Cape Town by means of the progeny of Bont ticks taken in the Eastern Province from infected goats. In this way, therefore, the very striking observations of the late Mr. Webb has been proved to be correct.

We are not, however, yet able to say that Heart-water is not conveyed by any means other than the Bont tick.

## 21.—ON THE PRODUCTION OF A MALARIAL FORM OF SOUTH AFRICAN HORSE-SICKNESS.

BY ALEXANDER EDINGTON, M.D., F.R.S.E., DIRECTOR OF THE COLONIAL BACTERIOLOGICAL INSTITUTE, CAPE COLONY.

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In my Report as Director of the Bacteriological Institute for the year 1901, I have detailed at considerable length experiments having to deal with the production of a malarial form of Horse-sickness. I propose to summarize these details, and to recount in a brief form additional investigations which have been made to confirm the foregoing, and to eliminate every possibility of fallacy.

### THE PRODUCTION OF A MALARIAL FORM OF HORSE-SICKNESS.

During my earlier experiments, devised with the object of determining a method of protected inoculation against Horse-sickness, it may be remembered, I showed that donkeys could be inoculated with virulent Horse-sickness blood without being seriously affected thereby.

Also the remarkable fact was demonstrated that the blood of such donkeys, drawn about the tenth or eleventh day subsequent to inoculation, was capable of setting up a very modified fever in which remissions and intermissions were conspicuously noteworthy.

In the case of two horses inoculated with donkey blood, I observed one or two of the blood corpuscles to be infected with a parasite having a resemblance to the microbe of Texas fever (Red-water).

At that time I was led to suppose that the febrile attack induced by the donkey's blood had lowered the animal's resistance, and permitted it to acquire an infection of Red-water, to which horses in a good state of health are not susceptible.

Nevertheless I was never satisfied with such an explanation, and determined at a future date to make a further inquiry in order to elicit the truth.

More recently I published a method by which I had been able to "salt" some horses by means of a mixture of serum and preserved virulent blood.

During these experiments, however, it was noticed that the most startling differences were noticed, in different horses, in their resistance to the action of this virulent mixture.

I, therefore, determined upon carrying out special investigations, and, primarily, to reproduce experiments akin to those made with the infected-donkey blood.

Since, however, it had been demonstrated that the same virus passed through different donkeys produced different virulence in each case, it seemed advisable to make use of animals which should have, as nearly as possible, *the same primary resistance*.

Since, then, "salted" horses are, from the point of view of resistance, somewhat comparable to donkeys of high resistance, it was determined to make use of these animals.

The procedure adopted was to take a number of "salted" horses, each being capable of resisting very large doses of virulent Horse-sickness blood, to inoculate these with a small dose of virulent blood and to bleed them about the tenth day.

Blood drawn at this period of time was inoculated in doses of 20 cubic centimetres subcutaneously into small batches of clean horses.

These experiments were not made "en masse," but extended over a long period of time, from the 14th November, 1901, until April of the present year.

The results are set forth in the Appendix under a Report to the Under Secretary for Agriculture, dated April 22, 1902, of which the following is a summary. After the first inoculation, a period of time was permitted to elapse after which a second inoculation was made.

Inoculation.	Horse.	Salted Horse from which blood was used.	Date.	Result.
1st.	No. 1.	A	November 14.	Severe fever.
	No. 2.	A	"	"
2nd.	No. 1.	B	December 29.	Little or no fever.
	No. 2.	C	"	"
1st.	No. 3.	B	November 14.	Slight fever.
	No. 4.	B	"	Severe fever.
2nd.	No. 3.	Removed for other experiments.		
	No. 4.	D	December 29.	Slight fever.
1st.	No. 5.	C	December 4.	Severe fever.
2nd.	No. 5.	C	December 29.	Slight fever.
1st.	No. 6.	D	December 4.	Severe fever.
2nd.	No. 6.	C	December 29.	Slight fever.
1st.	No. 7.	A	December 6.	Slight fever.
2nd.	No. 7.	D	December 29.	More severe fever.
1st.	No. 8.	B	December 6.	Severe fever.
2nd.	No. 8.	C	December 29.	Long continued mild fever ending in death.
1st.	No. 9.	A	December 19.	Mild fever.
2nd.	No. 9.	A	January 19.	Severe fever.

Inoculation.	Horse.	Salted Horse from which blood was used.	Date.	Result
1st. 2nd.	No. 10. No. 10.	B A	December 29. January 19.	Mild fever. Slight attacks at intervals, culminating in a severe one at the 70th day, from which animal died of typical horsesickness.
1st. 2nd.	No. 11. No. 11.	B A	December 29. January 19.	Severe fever. Mild fever.
1st. 2nd.	No. 12. No. 12.	B A	December 29. January 19.	Mild fever. "
1st. 2nd.	No. 13. No. 13.	B A	December 29. January 19.	Severe fever. Very severe fever.
1st. 2nd.	No. 14. No. 14.	C A	December 29. January 19.	Mild fever. Severe fever.
1st. 2nd.	No. 15. No. 15.	C A	December 29. January 19.	Very severe fever. Severe fever.
1st. 2nd.	No. 16. No. 16.	C A	December 29. January 19.	Fairly severe fever. Severe Fever.
1st. 2nd.	No. 17. No. 17.	C A	December 29. January 19.	Very slight fever. "
1st.	No. 18.	D	December 29.	Very severe fever, ending in death.
1st. 2nd.	No. 19. No. 19.	D A	December 29. January 19.	Very severe fever. "
1st. 2nd.	No. 20. No. 20.	D A	December 29. January 19.	Mild fever. "
1st. 2nd.	No. 21. No. 21.	E F	January 31. February 24.	Mild fever. "

During these periods "control" animals were kept in the same stables, their stalls frequently changed for those previously filled by animals suffering from fever. Also these control animals were provoked from time to time by subcutaneous inoculations of the blood of goats dying from Heart-water, and of oxen dying from Veld-sickness.

In the foregoing series of experimental animals it was almost invariably found that where fever was induced, *intracorpuseular* or *malarial parasites* were found within the red blood corpuscles.

After the fever passed off, the parasite disappeared, but, where a second inoculation produced fever, parasites again made their appearance.

In the case of two horses which developed very severe fever, their blood, when mixed and inoculated intravenously into a clean horse, produced virulent Horse-sickness ending fatally.

It has formerly been shown that the blood of virulent Horse-sickness, when diluted with water and filtered through a Pasteur filter, is still virulent to horses. Thus the microbe in such blood must be infinitely minute.

Therefore, my experiments show that the parasite of the malarial form must be evolved from an infinitely small pre-existing *extrapulmonary* form.

The foregoing facts which were announced in the report referred to evoked some criticism in the direction of suggesting that another disease had gained access to my stables or on the other hand that the animals possessed the parasites already in their systems previous to being inoculated by me.

With a view to meeting these contentions and demonstrating in an incontrovertible manner the correctness of the former results, the following experiments were devised and carried out.

Immediately after the former experiments I obtained a number of horses from this area and six were placed in a new iron compound.

The same manner of inoculation was followed by the production of parasites somewhat sparingly in numbers in four of the animals.

During the following year the stables of the Institute were thoroughly cleansed with hot caustic potash solution (1 %) which was applied to every portion of the buildings by means of a powerful spray. Every crevice was very carefully washed out and after the place had been allowed to become thoroughly dry the same process, using however 1 % of Schering's Formalin, was applied.

All woodwork was put in a sound condition and the concrete floor was gone over very thoroughly by masons.

After these matters had been accomplished I obtained through the kindness of the Military authorities, at the request of the Honourable the Colonial Secretary, ten clean horses which had been recently landed at Port Elizabeth.

These were sent up by train, were brought straight to the Institute and were immediately placed into stalls.

Each horse had a special bucket for water which was filled into them and they were fed with dry forage.

Previous to attempting any inoculation of the animals they were kept in the stables for several weeks during which their temperatures were taken daily on five occasions and their blood frequently examined for any abnormality.

*Horse 27.* Was inoculated with 20 c.c. of the blood of "salted" Horse B (which had been inoculated ten days previously with 10 c.c. of preserved virulent blood taken originally from a horse dying of virulent horse-sickness) on the 4th December 1902. The temperature began to rise on the eighth day and on the tenth day parasites were found in the blood.

*Horse 28.* This animal was inoculated at the same time as the last but was kept in another stable. Its temperature began to rise

on the eighth day and parasites were found in the blood on the tenth day.

*Horse 29.* This horse was inoculated also from Horse B which however had not been re-inoculated so that its blood was drawn 51 days after inoculation. The temperature began to rise on the ninth day and parasites were found on the tenth day.

*Horse 30.* This animal was inoculated with the blood of Horse 27 on the 14th of January. The blood of Horse 27 at this period shewed very few parasites. The temperature began to rise on the ninth day and parasites were found in the blood on the tenth day.

*Horse 31.* This horse was inoculated with 20 c.c. of the blood of "salted" horse A (which had not been re-inoculated since the previous experiments, about a year previously and which since that date had been kept in an isolation stable carefully groomed and tended). The temperature began to rise on the tenth day and parasites were found on the eleventh day.

I now decided to re-inoculate this horse which was accordingly done with 10 c.c. of preserved blood and ten days later it was again bled and this horse (31) re-inoculated with 20 c.c. of the blood. On the tenth day following a slight rise of temperature occurred which immediately subsided.

I desire to lay considerable stress on this experiment because it has been suggested that the fever which follows the use of the blood of a "salted" horse that has been recently re-inoculated is due to the Horse-sickness, while the parasites are of the nature of accidental infection. In the present case we find fever induced by the blood of a salted horse which has not been inoculated for a period of about a year, while the blood of the same "salted" horse after re-inoculation fails to produce any degree of fever in the horse formerly inoculated with its blood.

*Horse 32.* I now took preserved virulent blood and inoculated a clean goat with 10 c.c. by intravenous injection. Ten days later this goat was bled and immediately the blood was mixed with equal portions of sterile glycerine and water. Twenty-four hours later I injected horse 32 with 10 c.c. of this blood. On the ninth day a rise of temperature began to be apparent and on the tenth day I found perfect specimens of the parasite in the blood.

*Horse 33.* This horse was inoculated with 20 c.c. of the blood of salted horse B which had not been re-inoculated since the former occasion eighty-two days previously. The temperature began to rise on the ninth day and parasites were found on the eleventh day.

*Horse 34.* I now took a horse which had been inoculated in the former experiments (a year ago) on repeated occasions with salted blood and also with blood in which parasites had been found. That horse however never shewed any parasites. I now bled this horse and inoculated horse 34 with 20 c.c. of its blood. On the ninth, tenth and eleventh days slight rises of temperature occurred and on the 16th day I found a few but typical parasites in the blood. The reaction in this case was but slight and the parasites very few as compared with the horses which had been inoculated from "salted"

horses. I now took a well kept horse which is used for riding purposes and which had been "salted" about six years ago. With the exception of the fever which it had when being "salted" this animal has always been in the best of health. I, therefore, inoculated it with 20 c.c. of blood which shewed innumerable parasites. No fever in the slightest degree was produced and no trace of parasites was to be found.

*Horse 35.* I bled a clean goat, and with its blood inoculated horse 35 with 20 c.c. No result followed.

I thereafter inoculated the goat with 10 c.c. of preserved virulent horse-sickness blood and ten days later the goat was bled. Being somewhat afraid that the inoculation of the blood might prove fatal (one cannot ever be certain of the reaction of horse-sickness passed through either donkeys, oxen or goats) I mixed it with sterile glycerine and water, and twenty-four hours later I inoculated horse 35 with 10 c.c. Some irregularity of temperature was at once set up, due most probably to local irritation of the foreign blood but as at the tenth day no real rise had occurred I re-bled the goat and inoculated 10 c.c. of the fresh blood into the horse. On the 12th day after, the temperature began to rise and on the 13th day parasites were found in the blood fairly numerous. Conclusions. These experiments therefore enable me to conclude as follows.

I. The blood of "salted" horses which have been regularly re-inoculated for several months (10 c.c. being used once a month) is dangerous to inoculate into clean horses if the blood is drawn ten or twelve days after the last inoculation. The former experiments were conducted in this manner and as a result several animals died.

II. If "salted" horses are rested for a few months and then re-inoculated with 10 c.c. of preserved blood, their blood, if drawn ten or twelve days later will set up a satisfactory fever without much risk.

III. The blood of "salted" horses which have not been inoculated for several months will also set up a reaction but the result will be irregular and uncertain.

IV. Horses which have been running in the coast areas near Albany may resist the inoculation of the blood of "salted" horses even when the latter blood is derived from animals which have been recently re-inoculated.

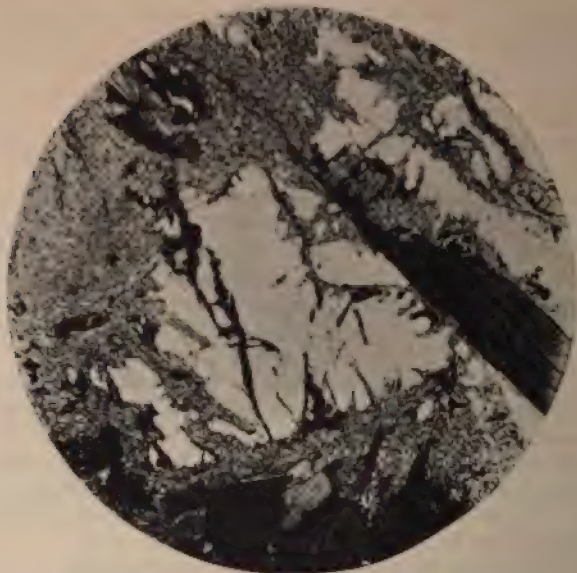
V. Blood taken from such animals as just stated, i.e. unsalted horses which resist inoculation with "salted" blood, does not give such an infection in clean horses as the blood of salted horses, even although the latter have not been inoculated for a period of a year.

VI. The blood of horse-sickness when passed through animals which are either naturally insusceptible such as the donkey, ox and goat, or animals which have acquired protection (salted horses) conveys a modified infection of horse-sickness which is malarial in type, and which is accompanied by the production of malarial parasites within the red corpuscles of the animal which is inoculated.

## 22.—THE MINERALS OF SOME SOUTH AFRICAN GRANITES.

By F. P. MENNELL, F.G.S., CURATOR OF THE RHODESIA MUSEUM, BULAWAYO.

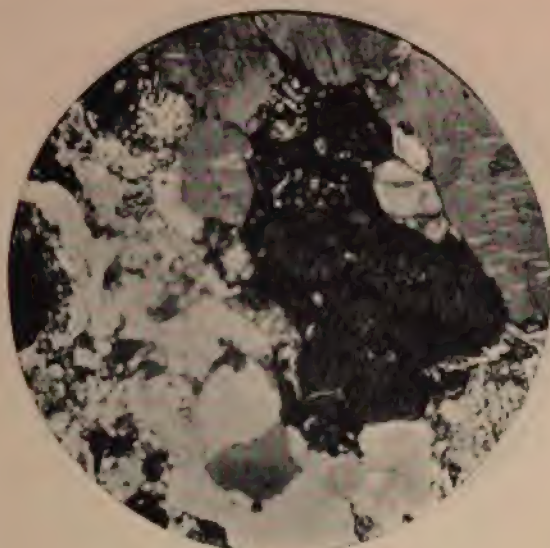
Plutonic rocks of acid composition are very extensively developed in Africa south of the Equator. These rocks present many features of interest and, especially under the microscope, many minerals may be recognised besides the usual quartz, felspar and ferromagnesian constituents. Thus the granite of Capetown itself is remarkably rich in accessories. Tourmaline, in particular is very



DECOMPOSING CORDIERITE, CAPE TOWN GRANITE.

abundant in places. In thin sections, it is of a yellowish brown colour frequently bordered and zoned with pale blue, while some crystals shew alternate bands of yellow and brown. The basic patches, which are no doubt derived from the fusion and subsequent recrystallisation of fragments of the adjacent slate are especially interesting. Some are largely made up of andalusite in good crystals or somewhat rounded grains. Cordierite is often seen and is sometimes quite fresh and almost indistinguishable from quartz, while in other cases it is entirely

replaced by the yellowish micaceous "pinite" pseudomorphs. The intermediate stages of the alteration may be well observed. Cordierite appears to be sometimes present in the normal granite, which also contains numerous small zircons, generally as inclusions in the biotite where they give rise to the usual pleochroic "halos."



BULAWAYO GRANITE.

In the Tati District of Bechuanaland, granite occurs as a modification of the prevailing syenite, and is chiefly remarkable for the amount of apatite it contains. This mineral sometimes forms crystals an inch in diameter: for the most part, however, they are of purely microscopic dimensions. They shew not only the usual cross-fracture but also complete dislocation of single crystals into a number of separate fragments divided by portions of the enclosing quartz or felspar. Sphene is abundant in this rock. It surrounds the iron ores in whitish granular aggregates which, unlike the variety leucoxene, are more or less transparent and shew brilliant interference tints when the sections are sufficiently thin.

The granites of Rhodesia are notable for the abundance of microcline, which is usually the dominant felspar. The now well-known Matopo granite is typically composed of microcline, quartz, and biotite with a little magnetite and some brownish sphene. The Bulawayo margin of the mass is a hornblende granite with microcline, oligoclase and orthoclase as the felspars. The accessories include large crystals of apatite, abundant yellowish sphene, a little magnetite and a good deal of pale yellow epidote. The last named mineral

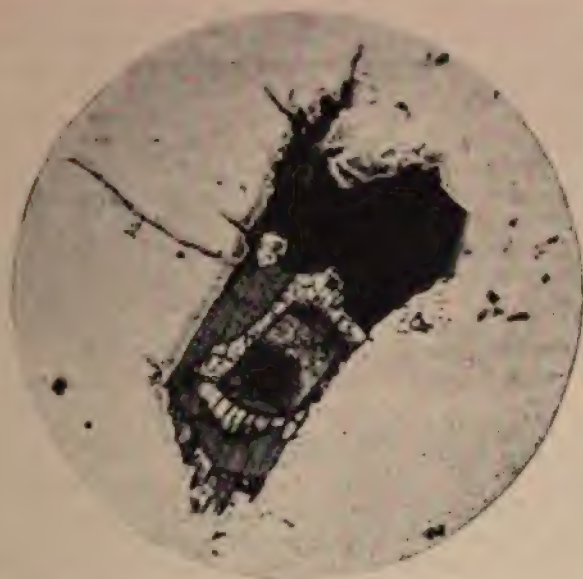
forms veins running through the granite in places, and fluorspar occurs in deep blue crystals in a similar way. Molybdenite occurs in a quartz segregation vein near Glenville, about three miles from Bulawayo.



MATOPO GRANITE

Several of the granites from Northern Rhodesia contain orthite (allanite). This mineral occurs in yellowish-brown idiomorphic crystals or rounded grains. The pleochroism is not strong and the double refraction scarcely exceeds that of quartz. A rock from the Jibuyi River contains numerous crystals about .5 to 1.5 mm. in length, occasionally twinned, and shewing inclusions of zircon, apatite, and magnetite. A granite from Kalomo shews zoned orthite surrounded by epidote with crystal outline, the latter being in turn enclosed in biotite. Epidote is extraordinarily abundant, and there is a good deal of sphene. A gneissose rock from the Wankie District of Matabeleland with orthoclase crystals several inches across, presents some special points of interest. Little pink garnets and minute brown granules which prove to be orthite can be detected by the unaided eye. The garnet is in the larger grains, but the orthite is much more abundant. It is more strongly pleochroic than in the rocks previously mentioned. It shews zonary banding and is frequently surrounded by biotite, but no enidote is present. The rock contains much apatite.

All these orthite-bearing rocks have a distinctly gneissic aspect which is sufficient to suggest a secondary or metamorphic origin for the orthite even apart from its association with epidote. The presence of garnet appears to point in the same direction. The fact of the epidote being idiomorphic towards the mica points, however, to its primary nature, and it may be remarked that the Northern Rhodesian rocks



BIOTITE ENCLOSING EPIDOTE WHICH SURROUNDS ORTHITE.

contain micropegmatite, a fact which appears absolutely conclusive as to their igneous origin. It may also be mentioned that fine-grained modifications of the Jibuyi rock contain correspondingly small crystals of orthite, and we seem accordingly driven to regard both orthite and epidote as normal products of the consolidation of a molten magna.

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### 23.—ON THE CLASSIFICATION OF THE THERIODONTS AND THEIR ALLIES.

By R. BROOM, M.D., B.Sc., C.M.Z.S.

The first attempted classification of the S. African Triassic reptiles was that given by Owen in his *Palæontology*. In the Order Anomodontia he placed three "families" or sub-orders—Dicynodontia, Cryptodontia, and Cynodontia. The types of these groups were respectively Dicynodon, Oudenodon, and Galesaurus.

Huxley in 1871 modified Owen's arrangement by placing Oudenodon with Dicynodon in the order Dicynodontia.

When in 1876 Owen published his *Catalogue of the Fossil Reptilia of South Africa* a large number of new forms had been discovered and much more was known of the details of structure. It was therefore possible for him to give a more satisfactory classification than that which had previously been advanced. Galesaurus, Cynochampsa, and a number of other allied genera were united together to form the Order Theriodontia, and the Order Anomodontia was retained for Dicynodon, Oudenodon, and a few other allied genera. It seems fairly evident that Owen all along regarded Dicynodon as the typical genus of the Anomodontia and that he considered he had made a mistake by including in his early classification Galesaurus with the Dicynodonts as one of the Anomodontia.

Between 1876 and 1888 comparatively little work was done among the S. African forms, but many new types were discovered in the Permian rocks of N. America, and described by Cope. These American forms belong to at least two well-marked groups. The first comprises a few genera, which in dentition resemble somewhat the S. African Theriodonts, but which are now known to differ considerably from the African types in many important points. For these (Clepsydrops, Dimetrodon, etc.) Cope founded the Order Pelycosauria. The reptiles of the other group are characterised by having the temporal fossa roofed. These Cope was at first inclined to place in the Pelycosauria, but he afterwards founded a new order for their reception—the Cotylosauria. Unfortunately he chose as the type of the Cotylosauria the genus *Empedias* which is very imperfectly known. Some of the other American genera (*Pariotichus*, *Pantylus*, etc.) seem to agree fairly closely with the S. African *Pareiasaurus*, but it is a little doubtful whether *Empedias* does. Owing to this doubt it is probably advisable at present to make use of Seeley's name *Pareiasauria* for those primitive reptiles with the temporal region roofed somewhat after the manner of the Labyrinthodonts.

Cope proposed in 1878 to form a large group—the Theromorpha—for these reptiles exhibiting mammal-like characters, and subdivided the group into the orders or sub-orders Anomodontia and Pelycosauria—the Anomodontia comprising the Dicynodonts, and the Pelycosauria the S. African Theriodonts as well as the American

forms. In 1889 he sub-divided the Theromorpha, or Theromora into 6 sub-orders, Placodontia, Proganosauria, Parasuchia, Anomodontia, Pelycosauria, and Cotylosauria.

In 1890 Lydekker in his Catalogue of the Fossil Reptiles in the British Museum made use of the term Anomodontia in practically the same sense as Cope's Theromora. This large order he sub-divided into the following sub-orders (1) Procolophonia, (2) Dicynodontia, (3) Theriodontia, (4) Pareiasauria. This classification, though the names are different, agrees fairly closely with Cope's. Lydekker omits the Placodontia whose affinities are doubtful, and the Parasuchia which he considers a distinct order, but his 2nd, 3rd and 4th sub-orders agree with Cope's 4th, 5th and 6th. The only difference with regard to Procolophon is that while Lydekker places it in a sub-order by itself, Cope unites with it its Palæohatterian allies.

In 1888 Seeley commenced his valuable series of "Researches on the Structure, Organisation, and Classification of the Fossil Reptilia," which have not only added greatly to our knowledge of the structure of the Triassic reptiles, but have made us acquainted with a number of new types. In his first classification he divided the Anomodontia into 8 sub-orders:—(1) Pareiasauria, (2) Procolophonia, (3) Dicynodontia, (4) Gennetotheria, (5) Pelycosauria, (6) Theriodontia, (7) Cotylosauria, (8) Placodontia. The name Gennetotheria was proposed for a group to include Propappus and Stereorrhachis, but was afterwards withdrawn.

In 1895, as the result of his researches, Seeley advanced a much more elaborate classification. The Anomodontia he divides into two principal orders—Therosuchia and Therochelonía—with possibly a third, Mesosauria. The Therosuchia he again divides into (1) Pareiasauria, including Procolophonia, (2) Gorgonopsia, (3) Dinocephalia, (4) Deuterosauria including Placodontia, (5) Theriodontia, including Lycosauria, Cynodontia, and Gomphodontia, (6) Endothiodontia, (7) ?Theromora, including Pelycosauria and Cotylosauria. The Therochelonía he sub-divides into the Dicynodontia and the Kistecephalia.

Though more elaborate this classification is much less satisfactory than Seeley's earlier one. So far as I am aware Seeley is the only writer who has suggested any great division between the Theriodonts and the Dicynodonts. Owen's first view of including the Theriodonts in the same order as Dicynodon was indeed much nearer the truth. Though the specialisation of the Dicynodonts entitles them to be placed in a distinct order or sub-order, they are more nearly allied to Theriodonts such as Galesaurus than are the primitive Theriodonts such as *Ælurosaurus* or *Ictidosuchus*. *Delphinognathus*, *Tapinocephalus*, *Placodus*, and even *Deuterosaurus* and *Rhupalodon* are so imperfectly known that it is impossible to say at present with any degree of certainty where they ought to be placed, but the case is different with the Endothiodonts. Both Owen and Lydekker recognised the close affinity between Endothiodon and Dicynodon, and the considerable number of new Endothiodont genera that have recently been discovered prove that

the affinity is much closer than has been hitherto believed. So nearly allied indeed are many Endothiodonts to Dicynodon and Oudenodon that I venture to affirm that a considerable number of skulls labelled in our museums as Dicynodon and Oudenodon are really Endothiodont.

Gadow in his recent work on Reptilia (1902) divides the Theromorpha into 4 sub-orders. (1) Pareiasauria, (2) Theriodontia, (3) Anomodontia, (4) Placodontia.

In the recent English translation of Zittel's Palæontology (1902) a classification is given which does not differ very greatly from that of Gadow. The Theromorpha is divided into (1) Pareiasauria, including Pareiasauridæ, Pareoticepæ, and Diadectidæ, (2) Theriodontia, including Galesauridæ, Deuterosauridæ and Tritylodontidæ, (3) Anomodontia, and (4) Placodontia. The Pelycosauria are regarded as a sub-order of the Rhynchocephalia.

Before proceeding further with the consideration of the classification, it will be well to look at one of two of the more recent observations on the structure of some of the principal types.

#### PROCOLOPHON.

This little primitive lizard-like reptile was first placed (1876) by Owen in the Theriodontia, apparently less on account of any Theriodont affinities, than because he did not know where else to put it. Seeley in 1878 described three imperfect skulls from Donnybrook, S. Africa—the same locality as Owen's specimens came from—and says "I see no reason to hesitate on the evidence detailed, in regarding it [Procolophon] as a fossil Rhynchocephalian." In his later works Seeley was much more impressed by its affinities with Pareiasaurus. Lydekker though he places Procolophon in the Anomodontia points out that it "Appears to present an approximation in several points to the Rhynchocephalia." While Cope unites Procolophon with Palæohatteria, Homœosaurus, and a few other genera to form the order Proganosauria.

As almost every detail of the structure of Procolophon is now known it can be definitely asserted that the affinities are very much more with Palæohatteria than with any of the Theriodonts, Anomodonts or even with Pareiasaurus.

Procolophon has well developed abdominal ribs, each composed of a series of pieces; the vertebræ are notochordal; the scapula is a short broad bone without a distinct acromion; the digital formula for the manus is 2, 3, 4, 5, 4, and for the pes 2, 3, 4, 5, ?; the lower jaw has a distinct coronoid element; and the pubes and ischia are flat plate-like bones resembling those in Palæohatteria except that the pubic foramen is near the middle of the bone. As the posterior cranial region of Palæohatteria is unknown, it is impossible to say in what degree it differs from that of Procolophon, but as there is such close agreement in the other parts of the skeleton it becomes necessary to place Procolophon somewhere near to Palæohatteria, and until the cranial structure of Palæohatteria is fully known it will perhaps be safer to make the Procolophonia a distinct sub-order.

## PELYCOSAURIA.

The researches of Baur and Case have conclusively shown that the Pelycosaurians are distinct in organisation from the Theriodonts of the Galesaurus type, and are more nearly allied to the Rhynchocephalians. Though the Pelycosaurians have two temporal arches they show in many points affinities with Procolophon especially in the structure of the limb bones. Whether Pelycosauria and Procolophonia should be regarded as distinct orders or as sub-orders of the large order Rhynchocephalia is a matter of little importance so long as it is recognised that the affinities are with the primitive Rhynchocephalians rather than with the Anomodonts and Theriodonts.

## PRIMITIVE THERIODONTS.

For some years it has appeared to me that in the order Theriodontia as generally accepted are included a number of forms not very nearly related to the typical genus. The palate of *Ælurosaurus*, though only imperfectly known, is manifestly so very different from that of *Galesaurus*, that if no other evidence were forthcoming it would be necessary to remove *Ælurosaurus* from the typical Theriodonts.

Having recently, at the request of Mr. W. L. Sclater, made an examination of the reptilian fossils in the South African Museum, I came across one or two interesting small Theriodont skulls that had been for many years in the Museum. The most perfect of the specimens, which I propose to name *Scylacosaurus Sclateri*, shows, after having been developed, almost every detail of the structure of the palate. And though the palate probably agrees fairly closely with that of *Ælurosaurus*, it is entirely different in type from that of *Galesaurus*, *Cynognathus*, or *Gomphognathus*. Externally the skull differs but little from that of *Ælurosaurus*, though the snout is longer and more slender. On each side there are six incisors, followed by two canines, of which the first is very small and the second large. There appears to be a third canine about as large as the second, but which is not yet functional. Following the canines are seven, or possibly eight, small pointed molars.

The palate in type is essentially Rhynchocephalian. The internal nares are situated in front, as in the *Sphenodon*, and separated from each other by the long, narrow, paired "vomers" (or prevomers, as I believe they ought to be regarded). In front these paired "vomers" meet a pair of short premaxillary palatine processes, while posteriorly they form a considerable part of the hard palate, separating the palatines and articulating with the anterior ends of the pterygoids. The maxillaries form no part of the palate—the palatines bearing the same relations to the maxillaries as is seen in *Sphenodon*. The pterygoids have well developed lateral processes, which are supported by a pair of transpalatines.

As the palate is essentially different in type from that found in the typical Theriodonts, it seems advisable to refer the Theriodonts of this type to a new order, for which I propose the name *Therocephalia*. The forms previously known which belong to this same order are *Ælurosaurus* and *Ictidosuchus*, and probably *Titanosuchus*. *Lycosaurus* has, according to Seeley, a palate similar to that in *Cynognathus*. In *Ælurosaurus* there are teeth on the pterygoids, and probably on the palatines and "vomeres." In *Scylacosaurus* there are a few teeth on the pterygoids, but there are apparently none on the palatines or "vomeres."

The shoulder girdle is known in *Ictidosuchus*, and is characterised by the absence of a distinct acromion, and by the fact that the precoracoid foramen is entirely formed by the precoracoid (epicoracoid).

As the structure of the palate is probably less subject to variation than the structure of the temporal arch, it will probably be found convenient to place *Gorgonops* in this order even though its temporal region appears to be completely roofed. *Deuterosaurus* and *Rhopalodon* probably also belong to the same order, but owing to our ignorance of many important points in the structure of the skulls of these genera it is impossible at present to be certain.

#### THERIODONTIA.

It is unfortunate that of the type genus *Galesaurus* only the skull is known, and even that imperfectly. The genera *Cynognathus*, *Gomphognathus*, and *Microgomphodon* are, however, fairly well known, and it is probable that *Galesaurus* agrees in its general skeletal characters with these other genera. *Cynognathus* agrees very closely with *Gomphognathus*, but the differences in the structure of the molar teeth entitle them to be regarded as the types of two families—the *Cynognathidæ* and *Gomphognathidæ*—but the differences do not seem sufficiently marked to entitle them to subordinal rank. *Lycosaurus*, on the other hand, though very imperfectly known, may be the type of a distinct sub-order.

#### ANOMODONTIA.

The structure of the Anomodonts is much more thoroughly known than that of almost any other Triassic reptile. *Dicynodon* and *Oudenodon* agree sufficiently closely to be placed in one family, but *Lystrosaurus* is probably entitled to be made the type of a distinct family, as is also probably *Cistecephalus*. *Lystrosaurus* differs from *Dicynodon* in having distinct postfrontal and postorbital bones, in having a distinct preparietal bone, and in the absence of a cleithrum. The Endothiodonts also form a distinct family. Six distinct genera of Endothiodonts are now known, and though considerable differences exist between them, the occurrence of intermediate forms renders it advisable to group together all those Anomodonts with molar teeth on the maxillary and dentary bones to form the family *Endothiodontidæ*.

## CLASSIFICATION.

While it is impossible in dealing with imperfect fossil remains to do more in the way of classification than approximate to the truth, I advance the following scheme as the most satisfactory that can be done in the present state of our knowledge. One or two very imperfectly known forms which may be the types of new sub-orders, or even of orders, have been omitted from consideration, as the evidence is too slight to go upon. I refer to such forms as *Delphinognathus*, *Tapinocephalus* and *Sclerosaurus*. Most taxonomists have placed the *Placodontia* with the Theriodonts—Seeley going even further, and suggesting that they may form a division of the *Dentrosauria*. The order is, however, so imperfectly known that it is probably wiser to do, as has been done by Lydekker, leave it to stand alone. There is certainly no satisfactory evidence for placing it among the "Theromorpha," its affinities being quite as much, or probably more, with the *Sauropterygia*.

## RHYNCHOCEPHALOID ORDERS.

*PROCOLOPHONIA.*

Lacertiform reptiles. Temporal region roofed. Distinct postfrontals, postorbitals, squamosals, supra-temporals, and quadratojugals. Palate Rhynchocephalian in type; teeth on pterygoids and prevomers. Vertebrae notochordal, with intercentra. Sacral vertebrae 4. Abdominal ribs present. Scapula plate-like, with no acromion; no cleithrum. Humerus with entepicondylar foramen; phalangeal formula 2, 3, 4, 5, 4. Pubis and ischium plate-like, pubis pierced by pubic foramen. Ilium short and broad.

Family: *Procolophonidæ*.

Genus: *Procolophon*.

*PELYCOSAURIA.*

Moderately large reptiles, with enormously developed vertebral spines. Temporal region with two arches. Distinct postfrontals, postorbitals, squamosals, supra-temporals and quadratojugals. Quadrate small. Palate a modification of the Rhynchocephalian type; teeth on pterygoids, palatines and prevomers. Vertebrae notochordal, with intercentra. Abdominal ribs present (*Theropleura*). Scapula flat, with no acromion; no cleithrum. Humerus with entepicondylar foramen. Pubis and ischium flattened, divergent.

Family: *Clepsydropidæ*.

Genera: *Clepsydrops*.

*Dimetrodon*.

*Naosaurus*.

*Embolophorus*.

## THEROMOROUS ORDERS.

*PAREISAURIA.*

Small, medium, or large reptiles, with temporal region completely roofed. Distinct postfrontals, postorbitals, squamosals, supra-temporals and quadrato-jugals. Palate Rhynchocephalian in type; teeth on pterygoids, palatines, and prevomers. Vertebrae notochordal. Two true sacral vertebrae in Pareiasaurus. Abdominal ribs unknown—probably absent. Scapula with acromion process; a well developed cleithrum present. Humerus with entepicondylar foramen. Pubis and ischium ankylosed forming large median symphysis. Phalangeal formula unknown, but as certain toes have undoubtedly 4 phalanges, formula possibly as in Procolophon.

Family: Pareiasauridæ.

Teeth in a regular series on margin of jaws.

Genera: Pareiasaurus.

Elginia.

Family: Pariotichidæ.

Teeth in more than one series in one or both jaws.

Genera: Pariotichus.

Pantylus.

Hypopnous.

Otocoeilus.

Family: Diadectidæ.

Anterior teeth conical; maxillary teeth laterally expanded.

Basioccipital loosely articulated.

Genera: ? Empedias.

Diadectes.

Chilonyx.

*THEROCEPHALIA.*

Medium size reptiles, with temporal region supported by a single lateral arch. Postfrontals usually absent (present in Scylacosaurus), postorbitals and squamosals present, supra-temporals and quadrato-jugals absent. A well developed quadrate. Palate a slight modification of the Rhynchocephalian type. Teeth on pterygoids in Scylacosaurus and Ælurosaurus. Maxillary and premaxillary teeth differentiated as in Mammals into incisors, canines, and molars. Occasionally more than one pair of canines; molars simple. Scapula without an acromion process; probably a cleithrum. Manus and pes unknown.

Family: Scylacosauridæ.

Distinct postfrontals present. Teeth on pterygoids, but not on palatines or prevomers. More than one canine in each maxillary.

Genus: Scylacosaurus.

Family: *Ælurosauridæ*.

Teeth on pterygoids, and apparently also on palatine and prevomers. A single canine in each maxillary.

Genus: *Ælurosaurus*.

Family: *Ictidosuchidæ*.

No distinct postfrontals. A single canine in each maxillary.

Genus: *Ictidosuchus*.

? Family: *Deuterosauridæ*.

No palatal teeth.

Genera: *Deuterosaurus*.

*Rhopalodon*.

Family: *Titanosuchidæ*.

[Probably a distinct family. Characters very imperfectly known.]

Genus: *Titanosuchus*.

? Family: *Gorgonopsidæ*.

Temporal region roofed. Prevomers ankylosed. No palatal teeth known.

Genus: *Gorgonops*.

*THERIODONTIA.*

Medium sized reptiles, with temporal region supported by a single lateral arch. No distinct postfrontals, supra-temporals or quadrato-jugals. Quadrate rudimentary. A secondary palate formed by the maxillaries and palatines. Prevomers small. True vomer large. Trans palatines usually absent. Occipital condyle double. No teeth in palate. Scapula with a distinct acromion. Phalangeal formula 2, 3, 3, 3, 3.

Family: *Lycosauridæ*.

Molar teeth simple.

Genera: *Lycosaurus*.

? *Cynodraco*.

Family: *Galesauridæ*.

Molar teeth cuspid.

Genera: *Cynognathus*.

*Galesaurus*.

Family: *Gomphognathidæ*.

Molar teeth with broad flattened crowns.

Genera: *Gomphognathus*.

*Microgomphodon*.

*Trirachodon*.

*Diademodon*.

*ANOMODONTIA.*

Medium sized reptiles, with the temporal region supported by a single lateral arch. Postfrontals usually absent (present in *Lystrosaurus*). No supra-temporals or quadrato-jugals. Squamosals and quadrates large. Pramaxillaries united, toothless, and very large. An imperfect secondary palate formed by the maxillaries and palatines. True median vomer well developed. Prevomers absent. Occipital condyle, single tripartite. Scapula with a well-developed acromion. Cleithrum present in *Dicynodon*, absent in *Lystrosaurus*. Phalangeal formula 2. 3. 3. 3. 3.

Family : Endothiodontidæ.

One or more series of molar teeth present on maxillaries dentaries. Interclavicle a rounded plate.

Genera : Endothiodon.

Esoterodon.

Cryptocynodon.

Pristerodon.

Family : Dicynodontidæ.

Maxillary teeth absent, or present as a pair of tusks. No teeth on dentaries. Interclavicle elongated.

Genera : Dicynodon.

Oudenodon.

Family : Lystrosauridæ.

Dentition as in *Dicynodontidæ*. A pair of postfrontals present; also a distinct preparietal bone. Interclavicle small. No cleithrum.

Genera : *Lystrosaurus*.

? *Gordonia*.

? *Geikia*.

Family : Cistecephalidæ.

[*Cistecephalus*, though imperfectly known, is probably entitled to be regarded as the type of a distinct family. It differs from *Dicynodon* and *Lystrosaurus* in the structure of the quadrate and occipital regions.]

Genus : *Cistecephalus*.

[Addendum. 27th October, 1903. Since the above paper was read it has been discovered that a preparietal bone is not peculiar to the *Lystrosauridæ*, being present also in the other families of the *Anomodontia*.—R.B.]

24.—MORPHOLOGICAL AND BIOLOGICAL OBSERVATIONS ON THE GENUS *ANACAMPSEROS* L. (*RULINGIA*, EHRLH.).

BY DR. S. SCHÖNLAND, HON. M.A., OXON.

The genus *Anacampseros* is entirely restricted to South Africa. It is sharply divided into two sections: (1) *Avenia*, E. Mey., and (2) *Telephiastrum*, Dill., which are separated from one another chiefly by their inflorescences, leaves, and stipules, which make them very different in appearance. As we shall see later on, there is no difference in the seeds, though this is maintained by Sonder in the *Flora Capensis*, and by Pax in Engler and Prantl's *Natürliche Pflanzenfamilien* (III., 1b, p. 57). The section *Avenia* consists of five species, two of which (*A. Alstonii*, Schönl., and *A. recurvata*, Schönl.) have only recently been described by me, and one of which (*A. guinaria*, E. Mey.) is only known from Drège's collection. This section seems to have its headquarters in Namaqualand, and extends through the Karroo. In the most eastern parts of the Karroo *A. ustulata*, E. Mey. seems to be not uncommon. It has even been found on the Stormberg by Mr. T. R. Sim, where he has also discovered other plants hitherto believed to be restricted to carroid districts (e.g., *Crassula pyramidalis*). The section *Telephiastrum* has a similar distribution. Six species belonging to this section are recognised in the *Flora Capensis*. Two of these are, however, only known from short descriptions, and *A. arachnoides*, Sims, has, by various authors, been split up into several other species.

*A. Telephiastrum*, *A. arachnoides*, *A. filamentosa* are frequently grown in European Botanic Gardens. In addition to these I have for years grown four species belonging to the section *Avenia*. Their cultivation does not offer any difficulties, though through bad luck, or perhaps I ought to say bad management, I have recently lost two of them. I may here mention that with suitable management scarcely any of our South African Succulents offer any cultural difficulties. All they require, when planted in tins or pots, is a rich sandy soil with good drainage, protection from continued soaking rains and protection from the watering can indiscriminately handled by thoughtless persons. When planted out (at all events in Grahamstown) they do very well in sunny, fairly well drained situations. They have only to be kept free from weeds and are *never* watered.

My investigations of the genus *Anacampseros*, though carried on at intervals for several years, are by no means complete, but they have already yielded several interesting results which have induced me to give a short resumé of them.

I have already incidentally referred to the water-storing *fores* of *A. filamentosa* and to the water-storing tracheides in this and other species. I will now briefly consider what other provision is found for water-storage and protection from excessive transpiration.

In none of the species is there developed an epidermal system of water reservoirs such as we find in so many other succulents. The cuticle of the leaves is not particularly thickened, the stomata do not show any provision that could be interpreted as helping to protect them, except that in *A. filamentosa* (and perhaps in other species) they are slightly sunk below the surface of the epidermis. But all parenchymatous cells of the leaves and also of the cortex of the branches are rich in mucilage, and this no doubt is largely responsible for preventing the moisture contained in them being given off too rapidly.

The shape of the leaves also helps to a large extent in this direction. It is a fact on which I need not dwell, as it is too well understood, that any organ which approaches a spherical form is *eo ipso* well protected against excessive transpiration, as the ratio of surface and contents is so very much more in its favour than in organs which are flattened. In the section *Avonia* the leaves are exceedingly small, but expose a greatly rounded surface to the atmosphere, while in the section *Telephiastrum* they actually approach more or less the spherical form.

But all species of *Anacampteros* are particularly well protected externally. They all have wrappers composed of dead tissues, which are practically impermeable to water. I refer of course to the stipules. These behave, however, differently in the two sections of the genus.

In section *Telephiastrum*, where their main body is composed of stiff hairs, they close firmly round the buds and the apices of the branches. They then form such a dense felt that transpiration must be reduced to a minimum, if not stopped altogether. In older parts they become so far separated that they can scarcely afford any direct protection, but I find they prevent the dewdrops from running down the plants, and thus no doubt render an indirect service to them, reducing transpiration while the dew is evaporating. I made some experiments with *A. filamentosa* in order to see whether dew would actually be taken up by its aerial organs, but the result was negative, or at all events indecisive, though plants kept in a room and occasionally wetted above the ground retained their vitality longer than others which were not wetted, and even produced small flowers and ripened their seeds, but this could be best explained by a better retention of the moisture in the plant. The long hairs, other than stipular, in this and other species, which are also composed of dead cells even before the leaves are fully developed, evidently perform subsidiary services in the same direction. There are, however, in *A. filamentosa* and other species smaller hairs of peculiar structure which require further investigation.

The stipules of the species belonging to the section *Avonia* are developed as comparatively large, leaf-like, flat structures. They

are, in all but *A. recurvata*, Schönk., broader than the leaves, and completely cover them in. The buds and apices of the branches are wrapped up by them thoroughly, and in dry weather, except again in *A. recurvata*, they are closely pressed against the stem, so that transpiration is stopped altogether, but when the atmosphere is moister they open out slightly, so that the margin of the leaves is just visible. This is especially striking in *A. papyracea*, but can also be observed in *A. ustulata* and *A. Alstonii*. They may even then catch the dew, but again I have failed to satisfy myself that they actually absorb it, and my observations seem even to point to the conclusion that such an absorption does not take place.

THE FLOWER.—The general structure of the flower is well known. There are two sepals and five petals, both of which are different in shape in the different species, though ovate and oblong forms prevail. However, their minute description here would be of no interest. The *Flora Capensis* ascribes to the genus 15-20 stamens. In *A. ustulata* there are sometimes seven, but as a rule eight stamens, five of which alternate with the petals, while three are epipetalous, thus indicating the presence of an epipetalous whorl.

In *A. papyracea* I counted about 16 stamens, in *A. Alstonii* over 60, in *A. filamentosa* about 15, in *A. arachnoides* usually 27. It is very desirable that the origin of these various numbers be carefully traced, but I have not been able to do this yet. The pollen is globular, smooth. The ovary is globose in *A. papyracea*, *A. Alstonii*, *A. ustulata*, but more oblong in the species belonging to the section *Telephiastrum*, especially in *A. arachnoides*. When we come to examine the PLACENTATION, we find that this has hitherto been either loosely or in some instances even wrongly described. In the *Flora Capensis* it is stated that the seeds are affixed to a central placenta. Unfortunately this term is applied both to a free central placenta and to a central placenta which is connected with the roof of the ovary. Pax in Engler's *Natürliche Pflanzenfamilien* (III. 1, 6, p. 53) expressly states that all Portulacaceae have a free central placenta but I find that all species of *Anacampseros* (perhaps with the exception of *A. ustulata*, which requires re-examination) have a central placenta which is connected with the roof of the ovary. Its shape is different in the different species, but I need not here enter into such details. The style is usually cylindrical, of various lengths, but in *A. papyracea* it is practically absent, and the three stigmatic lobes are therefore nearly sessile.

The majority of the species of *A.* have very showy flowers. These all agree in this: that they open for a few hours, in some species in the afternoon only. Towards evening they close and never open again. In all these species self-fertilisation is not only possible, but it takes place regularly. I have never yet seen an insect on any of their flowers. I have also kept them in such a manner that insects could have no access to them, and yet ripe seeds are in every case produced. We have here, therefore, the curious fact that the show-apparatus with which these flowers are so liberally provided is not necessary to them for the

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As far as my observations go, it is only caused by the plants to press the anthers against the stigma when the flower closes again after having taken a short airing. It is, however, very desirable that accurate observations on this point should be made in their native habitats.

People who are fond of theorising will naturally conclude from my observations that *Anacampseros* is a genus which is passing away from the state in which it required insects for fertilisation, as the show-apparatus must at one time have been of considerable use in attracting insects. Apart from the want of observations on this point in the field, serious objections might be raised to this view, but in one species at all events, in *A. papyracea*, the show-apparatus does not open out at all any more. We read already in the *Flora Capensis* (II, p. 383) that in this species the flowers are included in the uppermost stipules, but this does not express very clearly what really happens. The flowers are not only included in the uppermost stipules, but they are closely covered over by them; they never open, and as they pretty regularly produce ripe capsules and seeds, they are strictly *cleistogamous*. I have watched this species for years, and have never seen any flowers behave differently. *A. papyracea* is, therefore, as far as we know, the only plant in which none but *cleistogamous* flowers are produced.

**FRUIT AND SEED.**—Some time after fertilisation, and shortly before the seeds are ripe, the capsule is raised by the elongation of the pedicel. This is especially striking in *A. papyracea*, as in this way the capsule becomes free from the uppermost stipules. The structure of the capsule is pretty uniform in all species, differing only in unimportant details, but curiously it has, as a rule, been incorrectly described. Sonder in the *Flora Capensis* (II, p. 382) describes the capsule as "conical, 1-celled, 3-valved, the valves often longitudinally divided, and then apparently 6-valved."

Pax in Engler's *Natürliche Pflanzenfamilien* (III., 1b, p. 57) says:—"Capsule conical or oblong, 3-valved, with fleshy epicarp and membranaceous endocarp, valves often longitudinally divided, and then apparently 6-valved." Bentham and Hooker (l.c. I., p. 157) give a fairly accurate description, in which they follow Fenzl.

In all species the two sepals and the petals with the attached stamens close firmly together into a more or less cylindrical structure, which eventually becomes detached at its base in the form of a cap. Inside this structure the capsule is developed. The pericarp divides into an outer fairly hard, almost horny (*not* fleshy) epicarp, which also becomes detached at its base in the form of a conical cap, and frequently remains attached to the conical cap formed by the floral envelope. This cap, formed by the epicarp, is split at its base sometimes in three parts, in other cases in six parts. In the case of *A. Alstonii*, each of these six parts is again slightly divided at its base. There remains now, when the seeds are ripe, a basket-like structure, open above, formed, in the case of *A. Alstonii*, by six connivent oblong lobes, chiefly composed of strong fibres, and the interval between them occupied by a single fibre, the whole

being formed by the endocarp. It is this structure which probably has as a rule been looked upon as the whole capsule, but, as we have seen, this is erroneous, and as at this stage the placenta is free above, we may also look to this stage as the source of the incorrect description of the placentation.

The seeds again require our attention, as they have also been hitherto described incorrectly. Sonder (l.c. p. 382) describes them as winged. Bentham and Hooker (l.c. I., p. 157) as "angular or laterally compressed, 3-winged or nude." Pax (l.c. p. 57) says:—"Seeds angular or compressed, 3-winged or without wings," but though the seeds differ in slight details in the different species, they are again surprisingly uniform generally speaking. They all arise from campylotropous ovules, in which the chalazal portion is somewhat longer than the micropylar region. The result is that both ovules and the seeds are obliquely club-shaped. They are covered with very minute papillae, which in some species are a trifle larger than in others, and it is just possible that these may have given rise to the view that the seeds are winged. With reference to the endosperm in *Portulacaceae*, Pax mentions that it is scanty (l.c. p. 51). I have sectioned only the seeds of one species, *A. filamentosa*, and find that it is devoid of any endosperm. If this is the case in other species also, the genus *Anacampseros* should be placed in a rather isolated position amongst *Portulacaceae*, to which some of its other characters may also entitle it.

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25.—ON SOME STONE-IMPLEMENTS IN THE COLLECTION OF THE ALBANY MUSEUM.

BY DR. S. SCHÖNLAND, HON. M.A., OXON.

Apart from the so-called "digging-stones" of the Hottentots and Bushmen, their stone-hammers, stone-mortars, and stone-pipes, our knowledge of South African stone-implements is very recent. We look in vain for them in most of the innumerable books on South African travels, and in works on the South African natives. I think they were first mentioned by an anonymous writer (the late Dr. Dale?) in the "Cape Monthly Magazine." (New Series, Oct. 1870, I., No. 4, pp. 236-239), and even to this day the literature of the subject is very scanty, though these implements are found scattered all over the country, and though several intelligent collectors have paid attention to them. Large collections of them are found in the South African Museum, Cape Town, and the Albany Museum, Graham's Town, and many of them have also found their way to European collections. In the present paper I wish chiefly to deal with a few implements in the Albany Museum, the use of which is obvious, but which are noteworthy either for their rarity or neatness of workmanship, and, secondly, with some others the use of which is not quite clear to me, though suggestions with reference to them have been frequently offered. As these suggestions in every case amount to nothing but wild guesses, I do not feel justified in accepting them as conclusive, and my object in bringing these doubtful implements to your notice is therefore chiefly to submit them to an assembly amongst whom I hope there are some who can give some more definite information about them.

That some of these implements must have been, historically speaking, of very great age is a fact well known, but I cannot here deal with this aspect of the question beyond showing you an undoubted stone-implement found in Aeolian rock near East London by Mr. G. McKay, and presented by him to the Albany Museum some years ago.

The writer in the "Cape Monthly Magazine" already mentioned states that there is a remarkable similarity of type throughout those stone-implements which he has seen, whether European, South African, Japanese, or Australian. To illustrate this remark, I have placed a few European and South African implements side by side, and submit them to your inspection (*knives, scrapers, rough spear-heads, small perforated stones*). The truth of this remark will then at once be obvious to you. At first sight it may appear that this similarity is in most cases due to the fact that if certain stones are tapped in a certain manner they will always split in certain directions, but already in the specimens shown it will be seen that they are made of very diverse material, and this view becomes improbable, but it falls to the ground altogether when we examine some imple-

ments made of pure Quartz, of which I can also show you some South African ones, and we find there exactly the same cuts, and consequently the same design, as in those made of flint and quartzose sandstone. How the makers managed to cut the Quartz in this fashion is a mystery to me, and it certainly could only be the result of an art practised for ages, and handed down from generation to generation. The Quartz implements in the Albany Museum come from Namaqualand, Bushmanland, and Port Alfred, and their distribution seems therefore not to be governed by the occurrence of more easily worked material suitable for the manufacture of stone implements. There is some evidence also to show that there was some traffic carried on in suitable material [as also in paints] so that we find stone implements in localities which do not yield these materials. This was already noticed by Mr. A. Brown in the vicinity of Aliwal North ("Cape Monthly Magazine," New Series, I. p. 367). In spite of numerous enquiries, I have never yet met anybody who had seen an arrow made by South African natives with a stone arrow-head. A Mr. W. C. Palgrave forwarded in 1870 from the Northern border an arrow actually used by natives in that region, into the end of which a small leaf-shaped arrow-head of quartz crystal was inserted. This, as far as I know, is the only direct evidence to show that the things we call "arrow-heads" have really been used as such in this country. Bits of glass have also been used for the same purpose, but iron and bone tipped arrows seem to be the only ones used nowadays, and as the use of iron was known to the Hottentots and Bantu tribes before the advent of Europeans, it is most likely that stone arrow-heads were discarded even before Europeans landed in South Africa. Can it be that the Hottentots learned the use of iron from the incoming Bantu tribes, and then discarded the use of certain stone implements? This is one of the questions which a systematic exploration of the kitchen-middens along our coast will probably solve. My own knowledge of them is too fragmentary to be used for general conclusions of value, but it seems to me that there is a gradation observable in them, and that in the most recent ones there is less diversity in the stone implements than in the more ancient ones.

Leaving the innumerable scrapers, knives, and similar implements which are in our collection aside, I wish first to call your attention to a neat little saw which we owe to Dr. Howard, who found it in Bushmanland. Stone-saws from the Cape Flats are already mentioned in the "Cape Monthly Magazine" of 1870 (p. 238), but ours is the only instance that has come to my knowledge of a South African stone implement that must have been a tiny saw and nothing else. Its use was probably connected with the manufacture of arrows.

There are about 70 of the so-called digging stones in the collection of the Albany Museum. It seems to me that they have all been made of river-nodules, though there are two round lumps of rock, one from Griqualand West, the other from the Albert district, which the donors, Mr. E. J. Dunn and Dr. R. Kannemeyer, F.L.S.,

consider as digging stones in process of manufacture. In the first, however, I cannot see any clear evidence of human workmanship, while the other is evidently only a core from which chips have been struck. Most of them are made of a close-grained sandstone, only one, which is unfinished, is made of a hard plutonic rock. The holes are, as a rule, biconical, having been started simultaneously on both sides, but there are some with more or less cylindrical holes, which, according to a MS. note by Dr. Kannemeyer, were finished with an iron tool. As a rule the holes are central, only one stone has an eccentric hole. Many of these implements are more or less globular, and these are, according to Dr. Kannemeyer, of Bushman origin, while others, which are flat, are supposed to be of Hottentot manufacture. Whether this distinction is valid appears not to me to be doubtful. Most likely the shape of these implements was determined by the material most readily available.

The size of these implements varies considerably. The largest globular one has a diameter of  $5\frac{1}{4}$  inches, the largest flat one has a diameter of 7 inches, while the smallest is only a little over 1 inch broad. The weight also varies correspondingly, the largest weighing nearly 6 lbs., while our smallest only weighs not quite  $2\frac{3}{4}$  oz. (There is even a smaller one in the South African Museum.) That many of these stones were used for weighting sticks when digging out bulbs, roots, etc., seems to be beyond doubt. Several eye-witnesses have testified to this effect, but we must not suppose that even those which were suitable for this purpose were *exclusively* used for it. Thus, Mr. Harry Barber told me that he saw in the interior a native blacksmith using two as protection from the fire for the ends of the tubes of his bellows, and I have no doubt the Bushmen and Hottentots used them also for other purposes. A few of ours show signs that they were used as rubbers, or grinders, and hammers. There are also a good many which, on account of their small weight, could never have been of any use for weighting digging sticks. Most of these were probably used for the ready manufacture of knobkerries, and the writer in the "Cape Monthly Magazine" of 1870 (p. 239), already several times referred to, writes in confirmation of this view:—"From Wupperthal I hear that the oval perforated stones were used by the old Hottentot warriors as weapons of war, a stick of hardwood being thrust into the hole."

Sir John Evans, in his "Ancient Stone Implements, etc., of Great Britain" (2d. ed., 1897, p. 229, fig. 157), looks upon these round perforated stones as hammers, but very few of our specimens show signs that they have been used as such, nor does his figure of a specimen found at Stifford, near Gray's Thurrock, suggest in the least its use as a hammer, yet other specimens to which he refers show such apparent bruising at the end that they must have seen hard service, and for these his interpretation may be correct.

A number of specimens which he figures and describes (Chap. X., p. 238) "have cavities worked on either face, so deep and identical in character with those which, in meeting each other, produce the bell-mouthed perforations commonly present in the hammers

for hafting, that at first sight it seems difficult to say whether they are finished implements, or whether they would have become perforated hammer-heads had the process of manufacture been completed. Certainly in some cases the cavities appear needlessly deep, and conical, for the mere purpose of receiving the finger and thumb, so as to prevent the stone from slipping out of the hand; and yet such apparently unfinished instruments occur in different countries in sufficient numbers to raise a presumption that the form is intentional and complete."

Now, though we have a fair number of these unfinished implements, none of them show any signs of having been used for any particular purpose. Sir John Evans also suggested that some of them may have been discarded owing to difficulties having been met with in the boring operations, and this is certainly the case with some of ours, and the one with eccentric hole already referred to owes its peculiarity probably to the same cause.

I now come to some oblong stones which have been looked upon, and probably rightly so, as *hammers*. Some of them actually show signs of bruising at one end. They look like short, thick rolling-pins. If I remember rightly, Mr. L. Peringuey exhibited some similar, but larger and thicker, stones some years ago at a meeting of the S.A. Philosophical Society, and tried to show that stones of this nature were buried at certain spots to delimitate the borders of the areas which certain Hottentot hordes claimed as their own. Yet it seems to be worthy of consideration whether after all they may have been as a rule nothing more than prosaic rolling-pins for crushing and flattening out soft, especially boiled, food. At all events similar rolling-pins are still in use in Abyssinia. For pounding hard grains, etc., the Kafirs still use stone handmills with different mullers, but I am not aware that they used special implements for softer food material. Stones which have been interpreted as rolling-pins have also been found in Great Britain (Evans, l.c., p. 251).

There is one magnificent specimen in the Albany Museum, of which I have brought a photograph. It was ploughed up at Tharfield, about eight miles east of Port Alfred, and presented to the Museum by the late Hon. Dr. W. G. Atherstone. It is about 20 inches long. It is so ridiculously like a modern rolling-pin that it forms a great favourite with the lady visitors to the Museum, and it is very difficult to suggest any other use for it. My friend, Dr. R. Brown, told me that similar stones have been found in N.S. Wales, and have been described as "ceremonial stones," but as far as his recollection goes, there is nothing definite known about the use they have been put to.

It is, however, possible that this and similar stones may have been used for the preparation of karosses, which formed an important item in the daily life of the primitive natives of South Africa. An old Kafir told Dr. Atherstone that stones like the last one were used to shape assegai-heads, but I am afraid this information cannot be relied upon, since Kafirs and other native races will tell one anything one wishes, except the truth.

Another implement of which I am showing a photo was ploughed up in Lower Albany, and presented by the discoverer, Mr. Baines. On the photo it looks exactly like a chisel. It is made of a long slab of quartzite, originally rectangular in transverse section, but slightly trimmed for about  $\frac{2}{3}$  of its length in such a manner that the edges have been rounded off. One end has a sharp edge. As it is 21 inches long, its former use as a chisel is most problematical. I have suggested that it may have formed a portion of a trap by which small game was killed, but I do not feel at all confident that this interpretation is correct.

Amongst the best known implements which have been found, though in limited numbers, all over South Africa are oval stones, which are grooved on one side. They have been looked upon, and probably rightly so, as "whetstones for sharpening and bringing to a point, pins and other implements of bone, and they seem well adapted for such a purpose, and are still so used by the Eskimos. They may also have served for smoothing the shafts of arrows. "Serpentine pebbles with a groove in them are used for straightening arrow shafts by the Indians of California, and shaft rubbers of sandstone have been found in Pennsylvania" (Evans, l.c., p. 268). As a rule, South African ones are very convex on the surface, and slightly so on the back. We have, however, a portion of one found near Port Alfred, which is made of a rough piece of stone that has only been smoothed on the grooved surface.

With these stones that have only one groove, another found near Upington, and presented by the Hon. Mr. Justice Jones, has been placed, which has no less than eight grooves, fairly evenly distributed on the longer sides of an egg-shaped body. I must, however, admit that if this implement has been used as a whetstone, I cannot see the use of this number of grooves, which are all of approximately even depth. When I first saw it, it reminded me of a wooden tool which ropemakers use. They let the strands which they wish to combine to a rope run along the grooves, and while it is held steady the turning wheel can only twist the strands between the wheel and this implement. Now, considering that to this day the Bushmen make very nice string, of which they manufacture the nets to carry with them ostrich eggs filled with water, it is not improbable that our implement was really used for rope-making. In any case, the suggestion should be considered until a more likely one is brought forward. There is one specimen in the collection of the Albany Museum which may have been used as a spindle whorl. In any case, I cannot suggest any other use for it. It is made of soapstone. It was found at the junction of the Vaal and Orange Rivers, and presented to the Museum by the late Mr. P. Nightingale. It is a flattish perforated disk, gradually tapering to a sharp edge. It is about 4 inches in diameter, and the hole in the centre is about  $\frac{3}{4}$  in. across. According to Sir John Willoughby, hard clay disks, having a small hole in the centre, are used by the natives (of Mashonaland), even to the present day, in spinning bark fibres and thread made from the

wild cotton which is to be found in various parts of Mashonaland. These are probably identical with the clay-whorls found by Messrs. Bent and Bryce at Zimbabwe, similar to those found in great quantities in the ruins of Troy. (Hall and Neal, "Ancient Ruins of Rhodesia," 1902, p. 142.)

Stone-disks of a similar nature are of frequent occurrence in Great Britain and elsewhere. With reference to these, Sir John Evans remarks (l.c., p. 391):—"In spinning with the distaff and spindle, the rotatory motion of the latter is maintained by a small fly-wheel, or 'spindle-whorl,' very generally formed of stone, but sometimes of other materials, with a perforation in the centre, in which the wooden or bone spindle was fastened, the part below the whorl tapering to a point so as to readily twirl between the finger and thumb, and the part above being also pointed, but longer, so as to admit of the thread when spun being wound round it, the yarn in the act of being spun being attached to the upper point." "Spindle-whorls vary considerably in size and weight, being usually from an inch to an inch and a half in diameter, but occasionally as much as from two to three inches." If it is objected that where this specimen was discovered no suitable material is found for spinning purposes, we can, apart from Sir John Willoughby's testimony, again refer to Sir John Evans, who states (p. 390) that the principal fibrous materials in use in the Lake dwellings of Switzerland were bast from the bark of trees (chiefly the lime) and flax. Now, the bast of trees is to this day used by Bechuanas and Bushmen for making cords, and, therefore, this objection falls to the ground. I am, however, far from asserting that Bushmen knew the art of spinning in the stricter sense of the word. But it is by no means impossible. The conviction has gradually been forced upon me that we do not know the true Bushman, or that at all events there were Bushman tribes before the advent of Europeans, which in a sense had a comparative high degree of civilisation, which disappeared when they became mere hunted animals. Where this civilisation came from, whether by contact with the race which left its architectural monuments in Mashonaland and elsewhere, is more than I can tell or care even to guess.

There is, lastly, a possibility that this perforated disk may have served merely as a personal ornament. It is a well-known fact that Bushmen and other South African tribes used to string up small perforated disks of ostrich-shell to be worn as chains. We have also a few small perforated stone disks, which probably served a similar purpose. We have further in our collection three stone rings, which may possibly have been used as armlets, or in any case they cannot very well have been anything else but personal ornaments. The first was found in Gcalekaland by the Rev. Canon Woodrooffe. Its outer diameter is  $4\frac{1}{2}$  inches, and the diameter of the perforation is  $2\frac{1}{2}$  inches. It tapers gradually from the edges of the hole to the outer circumference, where it is very thin. Its shape is, therefore, similar to the brass rings worn formerly by some Basuto tribes (especially the women of the Royal house) round their necks.

The second was found in the Peddie district. Its outer diameter is  $3\frac{1}{4}$  inches, the diameter of the perforation is  $1\frac{3}{4}$  inches. It is thickest in the middle, but has no sharp edges.

The third was found near the junction of the Vaal and Orange Rivers by the late Mr. P. Nightingale. It is rather thinner than the others. Its outer diameter is  $4\frac{1}{2}$  inches, the hole is  $2\frac{1}{4}$  inches across. Stone rings of different sizes have also occasionally been found in Great Britain. Owing to their sizes they can scarcely have been used as armlets, but in shape they come close to ours. Thus the figure of one from Ty Mawr given by Sir John Evans (*l.c.*, p. 419, fig. 385) might, apart from minor details, stand for a figure of our Peddie specimen.

While the manufacturers of stone implements in South Africa were not devoid of a certain amount of skill, which must excite our admiration, while their arrow-heads, perforated stones, their "rolling-pins," their stone rings, indicate that there was not only skill but an inheritance of trade-tricks handed down from generation to generation, which were faithfully adhered to by the masters of the craft, it is astonishing that so far it has been impossible to find any evidence of progress in the manufacture of stone implements in South Africa, such as we know has taken place in other countries from palæolithic times to the time when stone implements were given up. Generally speaking, we can say that not only has the stone age persisted in South Africa until comparatively recent time, but that the palæolithic age has persisted here to the same extent. This is especially shown in the almost entire absence of polished stone implements. Even such beautiful implements as our Tharfield rolling-pin have only been smoothed down, their surface can scarcely be called polished.

The exception to prove the rule is a muller made of diorite found in the mud of the Gats River, in the Sneeuwberg, by a Mr. Murray, and presented by him to the Albany Museum. As no photograph or description could do justice to this beautiful implement, I have brought it to show you. When you consider the hardness of the stone and the difficulty of working it, you will agree with me, no doubt, when I consider it the gem of our collection.

In the discussion which followed, Mr. L. Peringuey, F.E.S., etc., Assistant-Director S.A. Museum, showed some implements found on the Cape Flats and elsewhere which had been worked on both sides, and would be classed as neolithic in Europe. Dr. Schönland acknowledged this, yet there is no evidence to show that these were of later period than the majority of the others. At the same time he readily admitted that further investigations may upset our present ideas on this subject, on which systematic investigations on a big scale are highly desirable.

[*Postscript.*—The author found recently in the North Eastern Kalahari, about 43 miles north of Serowe, on the site of an ancient Bamangwato settlement, a stone-bear (about  $\frac{1}{2}$  inch in diameter)

which is made on the plan of the "digging stones" with double-bell mouthed perforation. The chief Khama told him that his people used to make such beads. This makes it likely that other small stones of similar workmanship were also used as personal ornaments by the primitive inhabitants of South Africa, and it may also serve as a caution against ascribing all stone-implements found in South Africa to Bushmen and Hottentots.. 21st October, 1903. S. Sch.]

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## 26.—THE DEVELOPMENT OF SOME SOUTH AFRICAN FISHES.

BY J. D. F. GILCHRIST, M.A., B.Sc., PH.D., GOVERNMENT  
BIOLOGIST TO THE COLONY OF THE CAPE OF GOOD HOPE.\*

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The necessity for ascertaining information as to the development of fishes has arisen in Cape Colony as it has in other countries, and the want of such information has caused considerable difficulty in legislative matters. Thus it is commonly alleged that the practice of netting, as carried on in the Zwartkops, the Buffalo, and other tidal rivers of South Africa, has proved destructive to the eggs and spawn of fish, those of this opinion asserting with confidence that quantities of fish spawn are brought on shore by the net and left to perish. Another occasion on which the same question arose was on the commencement of trawling in False Bay, and on the Agulhas Bank, near Mossel Bay, by the Government steamer. It was thought that the dragging of the net along the bottom of the sea caused the destruction of great quantities of the eggs and young of food fishes. The Cape fishermen, an observant and intelligent class of men, were of opinion that the fish supply was being seriously endangered by such operations, and the question was felt to be so serious that a Commission of Parliament was appointed to enquire into the matter. The evidence seemed to indicate that many of the common fishes may deposit their eggs on the bottom of the sea. Thus one fisherman, who had had an experience of a life time in fishery matters in False Bay, was of opinion that all fish spawn was on the ground, and that the trawl runs across it, and must destroy it (*vide* Report of Select Committee, p. 13). Another equally experienced fisherman thought, however, that the spawn floats on the surface (p. 18). A fisherman of fifteen years' experience at Kalk Bay could not agree with this (p. 21), while another was of opinion that the eggs floated, and could be taken up in the hands out of the water. A practical fisherman of forty-three years' experience considered that the spawn is on the ground, and also floats, adding the additional interesting information: "I have seen the spawn—whether of fish or not I cannot say, but it is alive—little round things like eggs, and they smell very nastily, like rotten pumpkins. I have seen it a foot thick on the water" (p. 24). Yet another witness thought that "the fish breed on the ground, but the spawn does not stop at the bottom." Another practical man gave evidence to the effect that the klip-fish deposits its spawn on the seaweed, and it is there destroyed by the trawl (p. 37). On the other hand, in all the instances where the mature eggs had been procured and successfully fertilized on the Government steamer, the "*Pieter Faure*," they were found to float on the surface of the water, and only after the larvae had been hatched out some

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\* For the full paper see "Marine Investigations," Vol. II.

time did they begin to sink to the bottom. It was also brought to the notice of the Commission that it had already been demonstrated in Northern waters that there was only one fish of practical economic importance depositing its eggs on the bottom (the herring), and only a small species of herring (*Clupea ocellata*), of little value to the present fishermen, occurs in the Cape seas. On the whole it was felt very necessary that further enquiries should be made into the subject and definite information obtained. Recently facilities have been afforded by Government for more careful examination on shore of the eggs and larvae procured by means of fine nets and from the mature fish, and the following is a review of some of the most important results.

The eggs and larvae of the following fish are dealt with:

Chrysophrys globiceps, C. & V.	...	White Stumpnose.
„ gibbiceps, C. & V.	...	Red Stumpnose.
Dentex argyrozona, C. & V.	...	Silver Fish.
Pagellus mormyrus, Linn.	...	Zeverrim or Zee-basje.
Agriopus verrucorus, C. & V.	...	Horse Fish.
Trigla kumu, Less.	...	Red Gurnard.
Sciæna aquila, Risso.	...	Kabeljaauw.
Clinus superciliosus, Linn.	...	Klip-fish.
„ capensis, C. & V.	...	„
Synaptura pectoralis, Kaup.	...	Sole.
Achirus capensis, Kaup.	...	„

The ova and larvae of fish as yet unknown are also described. These, designated Species I-XI, were found in fair abundance in tow nettings, and two (sp. I & II) were found in dredging, being attached to shells and rocks. One species (XI) was procured in the dredge and consisted of a cluster of eggs perhaps demersal. With the exception of these last three all the eggs examined were found to be pelagic or floating eggs.

Only two instances among the teleostean fishes have been found in which the young is brought forth alive. This is the case in two species of Klip-fish (*Clinus superciliosus* and *Clinus capensis*).

## 27.—THE TEACHING OF BOTANY.

BY H. H. W. PEARSON, M.A., F.L.S., PROFESSOR OF BOTANY,  
SOUTH AFRICAN COLLEGE, CAPE TOWN.

I should offer a word of explanation, if not of apology, for introducing to the notice of Section B a paper bearing this title. Among the objects of this association as stated in the constitution are: To give a stronger impulse and a more systematic direction to scientific enquiry; and to obtain a more general attention to the objects of pure and applied science. An interest in the Scientific Education of the country appears to be included in these projects. I believe that efficient and highly successful botanical teaching has for some time been carried on in more than one educational centre in the Colony. A new departure is however being made in Cape Town, and as opinions as to the best methods of teaching the subject are by no means uniform, it seemed to me that it would be of advantage to me, and perhaps not without interest to the section, if I should give a general outline of the course which I propose to adopt. Among the members of the section are well-known South African Botanists and experienced teachers, of whose criticisms I shall be glad to avail myself.

At the outset we have the question: what should be the aim of botanical teaching? The answer, I think, is in general terms: (1) to give to the students the best mental training which the subject is calculated to afford and (2) to furnish them with that knowledge of the subject which will be of the greatest use to them. With these aims before us, the problem is to map out such a course of study as is best calculated to realise them.

Botany is commonly described as an "observational" Science. Properly studied there is no doubt that it is eminently calculated to train the student in habits of exact observation—habits whose importance in practical life is as obvious as is the fact that they are remarkably deficient among educated people.

This is the first principle which should guide us in our methods of instruction. In the study of plants the student must learn his facts from plants, and not from the text-books or the teacher. This is a law, as of the Medes and Persians, and the only pretext on which it may be broken is the inability to obtain suitable material. That this may occur as rarely as possible it is imperative that the teacher should have access to a botanic garden of some kind and some voice in the selection of plants grown for teaching purposes. It will usually be impracticable for him to obtain his specimens from the field. Wherever possible the student should see fresh material; but even in this climate there will frequently be occasions on which fresh specimens must be replaced by those preserved in spirit. Another

point which must not be overlooked is the importance of drawings. The student cannot make too many, and the teacher should make a point of examining them all before they leave the laboratory. Each hour spent in the lecture-room should be supplemented by at least twice that period in the laboratory, where the student should carefully and exactly record his own observations on the plants or parts of plants which have been the subject of the lecture. This will also afford an opportunity for an exchange of views between the taught and the teacher, the advantages of which are not small and may be considerable.

The student should first make acquaintance with objects already familiar to him whose size, form and characteristics, so far as they can be observed with the naked eye, should be noted with the utmost care and precision. The most suitable for this purpose are large seeds. Those of common *Leguminosae*, from their size, and comparatively simple structure should be first selected. Their external characters having become familiar, typical seeds will be dissected and their internal structure studied. The next step will be the dissection of an albuminous seed, preferably that of the Castor oil. For comparison with these two types the anatomy of the Pine seed, and afterwards that of the Date, will be considered. This will lead to a consideration of common forms of the seed, and their relation to seed distribution by various agencies. The next step in logical sequence is the observation and comparison of successive stages in the development of the seedlings resulting from the germination of seeds previously studied. The plants so obtained will serve as types upon which to found a study of the various forms assumed by the root, stem and leaf of the higher plants. These general notions of morphology will be accompanied by elementary physiological considerations, the purpose of which will be to lead the student to regard an effect as due to a preceding cause or combination of causes. A study of the morphology of the flower and fruit will follow naturally. The processes of pollination and fertilisation will be referred to, the detailed study of the latter being postponed until the student has acquired a working knowledge of the use of instruments.

Thus far no aids to observation, except occasionally the simple lens, have been called in. The student now knows something of the macroscopic characters of the higher plants. If he has not already been through an elementary course of general Biology, a few carefully selected types of the lower plants should at this stage be examined, special attention being given to their life-histories and simple physiological processes. If this can be combined with a similar study of a few simple animal types the student will acquire a grasp of the fundamental principles of Biology, without which his further study of Botany will be seriously hampered. A subsequent examination of the various forms of living and dead cells, the cell-wall and its changes, the contents of the cell, movements of the protoplasm, etc., leads up to a consideration of cell-groups or tissues, and their relative positions in the stems, roots and leaves of types of

the *Ferns* and *Flowering plants*. This will exercise a mental faculty which has been called "Visualization," viz., the power to form a solid transparent mental picture from the study of transverse and longitudinal sections of an opaque solid, and generally to build up complete ideas from isolated data. This branch of Botany is difficult, and one which more perhaps than any other strains the interest of the student. This is to some extent due to the fact that the organ whose anatomy is under consideration is usually treated merely as a dead object. Practical work in anatomy should however be enlivened as far as possible by experimental demonstrations bearing upon the functions of the organs studied. For example, the absorption of liquids by roots, and their response to various stimuli, should be the subjects of simple and easily intelligible experiments during the period in which the root-structure is being learned. Light will also be thrown upon leaf-structure by experiments on assimilation, and by a consideration of some well-marked variations in structure which are regarded as adaptations to different groups of external conditions. The simple physiological experiments here referred to should give the student a very definite idea of the relation of cause and effect, and enable him to estimate the value of the evidence obtained by putting a direct question to nature. In fact, they should be so carried out as to give him a real if elementary notion of the principles of research. The study of the general anatomy of the vegetative organs will prepare the way for a more detailed examination of the structure of the essential parts of the flower, which we were unable to deal with at an earlier stage. The student should by this time have acquired sufficient skill in manipulation to enable him to gain such an idea of the structure of the anther and the ovule, and of the development of pollen- and embryo-sacs as will enable him to understand the principles of fertilisation and embryo-formation in the Gymnosperms and Angiosperms.

Before this course is entered upon the ideal student will have followed a course of Nature study and will have become acquainted with some few plants, at least, of his native Flora. He may even have so much knowledge of the subject as is required by the syllabus of the University Matriculation Examination. Occasionally one meets with a student whose interest in the subject is such that while following a laboratory course he spends some of his spare time in collecting plants and possibly in forming a private herbarium. This spirit should be encouraged as far as possible by periodical Botanical excursions conducted by the teacher. The principal objects of these excursions will be to observe the plants in their natural habitats, the relations of one plant to another and of one plant-society to another, their forms and habits as evidences of the influence of the conditions under which they live. Incidentally the names of many plants will become familiar, though I do not regard this as a primary object of the excursion. In any case the student should be encouraged and helped to identify his plants for himself rather than be allowed to place his reliance upon the knowledge of another. With this end in view, from the plants collected upon the excursions a small

teaching herbarium and museum should be formed to which all serious students should have easy access. Besides familiarizing the mind of the student with his native plants, the study of herbarium and museum specimens has the additional advantage of correlating in a general system the types which have been used in the earlier part of the course. It is of even greater importance that a classified collection of living plants, to some extent grouped according to natural orders, should be accessible.

These experiences will be of immense value in preparing the way for the last stage of the elementary course, viz., the systematic study of the natural orders. As a further preliminary the men should have a little practice in what is commonly known as "Descriptive Botany," from which will be gained a knowledge of the more important technical terms used in botanical descriptions and of the use of floral diagrams. For this work living plants alone should be studied, the use of dried specimens being open to very serious objections. The natural orders selected for illustration should be those most commonly represented in the native flora, together with such smaller orders as may be necessary for the illustration of affinities. Every natural order should be illustrated by one or more types, and by such aberrant forms as may be obtainable and convenient. Specimens should be in the student's hands during lecture and afterwards in the laboratory careful dissections and drawings must be insisted upon.

The course, thus sketched out, if conscientiously done, should afford a sound knowledge of the general principles of the science which will render intelligible the second part of the programme, which in comparison with the foregoing may be termed the "advanced" course. This can be described in a few words. It comprises a systematic study of the vegetable kingdom. Each group from the Algae to the seed-bearing plants is dealt with in some detail. Its phylogeny, its systematic relation to neighbouring groups, the principles of its subdivision into sub-groups and families are described and the anatomical, morphological and physiological characters of the plants composing it are explained as far as possible. General questions of physiology will be gone into more fully than in the previous course and further experiments will be introduced. Among the phanerogams a further number of natural orders will be studied. In general, this advanced course will be designed to deepen and to give application to the principles learned in the elementary course.

Botanical work advanced beyond this stage should, in my opinion, be conducted on a somewhat different plan with the special object of bringing out the individuality and originality of the student. I should not propose to invite him to attend lectures beyond two or three short special courses. The main part of his work on the other hand will be of a practical character, and he should even be encouraged to undertake a promising piece of investigation, opportunities for which abound in this country. Side by side with this practical work he will follow a course of reading carefully arranged to give him an insight into the methods and results of recent investigations. The researches to which attention is directed

should be distributed over the whole range of the subject but, at the same time, there is no reason why the student should not pay particular attention to any branch which especially arouses his interest. His reading at this stage should include a study of the history of our subject. I do not think that he should be required to go into this in too great detail, though he might be expected to make himself well acquainted with the story of the advance of knowledge in the branch which he has most closely studied. In the present condition of our teaching organisation it is doubtful how much of this programme for an advanced course can be satisfactorily attempted. Such a course cannot be regarded as complete unless it includes special lectures and practical work on *Fossil Plants*, *Diseases of Plants*, *The uses of Plants*, and other branches of scientific interest. For the present however these are out of the question.

The scheme of instruction contained in this paper is a modification of that which is followed with a marked degree of success in more than one of the leading botanical schools of Europe, and experience has proved that when such a skeleton is clothed by an inspired teacher it is calculated to develop the student, to train his faculties, to give him a sound knowledge of the subject as a whole and at the same time to enable him to follow up a line of independent research.

Unfortunately, however, a teaching-course has usually to be considered with reference to an impending examination. No alternative to the examination-system has been discovered and the teacher has therefore to look beyond the true needs of his students to the requirements of the syllabus.

It will probably be objected that the course I have here sketched out fails in that in some respects it does not coincide with the syllabus of the examination of the Cape University. I must at once admit the objection. This however is not the place in which to discuss an examination-syllabus. My object has rather been to sketch out what, in my view, constitutes a rational course of instruction in Botany on the assumption that the training of the student rather than the requirements of an examination is the aim to be accomplished.

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## 28.—THE NATURE OF HEREDITY.

BY ARTHUR DENDY, D.Sc., F.L.S., PROFESSOR OF ZOOLOGY IN  
THE SOUTH AFRICAN COLLEGE, CAPE TOWN.

### INTRODUCTORY REMARKS.

IN response to the invitation which I have received to make some contribution to the proceedings of Section B of the South African Association for the Advancement of Science, I venture to bring before you some notes on a subject in which I have been deeply interested for many years, and in which, indeed, no student of nature can fail to be deeply interested. The problem of Heredity is one which lies at the very root of the Biological Sciences, but so difficult is it to grasp that a recent writer, entitled to speak with authority, states "that as to the essential nature of these phenomena we still know absolutely nothing."\* I venture to think, however, that some suggestions at least have been made by well-known writers which are of great value in helping us to form some conception of the true nature of heredity. More particularly I consider that the views of Herbert Spencer, Cope, and Detmer, to which I shall refer later on, have not received the consideration which they merit at the hands of biologists, and it will be seen that the ideas which I now venture to bring under your notice are to a large extent identical with those of the eminent writers mentioned.

Ever since the publication of Darwin's theory of "Pangenesis," what we may perhaps be allowed to term a materialistic method of explaining the phenomena of heredity and development has occupied the attention of many biologists. It has been commonly assumed that the observed facts of the transmission of characters from parent to offspring can only be explained on the assumption that the innumerable characters which any organism exhibits are represented by so many material particles—"gemmules" of Darwin or "determinants" of Weismann—which are stored up in the protoplasm of the germ-cells, an assumption which is indeed improbable when we remember the microscopic size of the cells in question and the number of characters which have to be taken into account, and which seems quite unnecessary when we remember how physical forces are known to act upon objects at a distance without the intervention of any material substance whatever. The well-known phenomena of magnetism and electrical induction, and especially such modern discoveries as that of wireless telegraphy, should alone be sufficient to put as on our guard against accepting as necessary any theory which assumes the existence of such inconceivably complex

\* Bateson, "Mendel's Principles of Heredity," p. 3.

arrangements and migrations of material particles as have been imagined by Darwin and Weismann.

It must not be supposed that I would deny for a moment that the inherited characters of an organism are intimately associated in some unknown way with certain material substances lodged in certain of the cells of that organism. On the contrary, I believe, with others, that these characters are associated with the chromosomes or darkly staining bodies of the nucleus, and that we may perhaps regard these chromosomes as the seat of complex systems of forces in somewhat the same way as storage batteries may be regarded as reservoirs of electricity, although of course this analogy can easily be pushed too far. Such an hypothesis as this, however, is a very different thing from the supposition that every ancestral character is represented in the germ cell by a separate particle which must undergo an elaborate series of subdivisions and migrations as the organism develops in order ultimately to reach its particular sphere of influence.

Darwin, it is true, regards his theory of pangenesis as a provisional hypothesis, but even supposing it to be valid so far as it goes, still it does not by any means go to the root of the matter. Even if his "gemmules" could be shewn to exist, still the theory does not explain in the least how these gemmules came to control the development of the particular cells with which they are believed to be associated, and it is the nature of this control which we really want to get at. The assumption of an immense number of material particles each representing some somatic character, or group of characters, does not really help us. As Herbert Spencer said long since: "We find ourselves again brought down to the persistence of force, as the deepest knowable cause of those modifications which constitute physiological development: as it is the deepest knowable cause of all other evolution."

Loeb also, in speaking of his wonderful researches upon fertilization, has quite recently made a similar statement, that he considers "the chief value of the experiments on artificial parthenogenesis to be the fact that they transfer the problem of fertilization from the realm of morphology into the realm of physical chemistry."

The principal exponent of the "Dynamic Theory" of Heredity is, however, the well-known American writer, Professor E. D. Cope, and his views will be found set forth at length in his work on "The Primary Factors of Organic Evolution," from which I take the following quotation:—

"The manner in which influences which have affected the general structure are introduced into the germ-cells remains the most difficult problem of biology. For its explanation we have nothing as yet but hypotheses. The one which has seemed to me to be the most reasonable belongs to the field of molecular physics, and it must be long before it is either proved or disproved. I have termed it a 'dynamic theory,' and it is in some respects similar to that subsequently proposed by Haeckel under the name of the 'perigenesis of the plastidule.' I have already referred to the phenomena of the

building or growth of the added characters which constitute progressive evolution as evidence of the existence of a peculiar species of energy, which I term bathmism. This is to be explained as a mode of motion of the molecules of living protoplasm, by which the latter build tissue at particular points, and do not do so at other points. . . . In bathmism we see the resultant of innumerable antecedent influences, which builds an organism constructed for adaptations to the varied and irregularly occurring contingencies which characterise the life of living beings. . . . The preceding statements do not, of course, constitute an explanation of the exact manner in which a stimulus which effects, say, the contraction of a muscle, effects molecular movements of the nuclei of the reproductive cells. This is a question of organic molecular physics, a science which has made scarcely a beginning. That the transmission of such influence is through nutritive channels, by the intermediation of a nervous structure where one exists, may be supposed. . . . If appears to me that we can more readily conceive of the transmission of a resultant form of energy of this kind to the germ-plasma than of material particles or gemmules. Such a theory is supported by the known cases of the influence of maternal impressions on the growing fœtus. Going into greater detail, we may compare the building of the embryo to the unfolding of a record or memory, which is stored in the central nervous organism of the parent, and impressed in greater or less part on the germ-plasma during its construction, in the order in which it was stored. This record may be supposed to be woven into the texture of every organic cell, and to be destroyed by specialisation in modified cells in proportion as they are incapable of reproducing anything but themselves. . . . In the process of embryonic growth, one mode of motion would generate its successor in obedience to the molecular structural record first laid down in the ovum and spermatozoid, and then combined and recomposed on the union of the two in the oöspore, or fertilized ovum. . . . The somatic cells retain only the record or memory of their special function. On the other hand, the reproductive cells, which most nearly resemble the independent unicellular organisms, retain first the impressions received during their primitive unicellular ancestral condition; and second, those which they have acquired through the organism of which they have been and are only a part. The medium through which they can receive such impression is continuous protoplasm."

I have quoted thus at length from Professor Cope's work because I believe that his views on the nature of heredity come nearer to the truth than those of any other writer, and the remarks which I have now to make are little more than an extension and amplification of Cope's argument. There are, in particular, three points upon which I do not think sufficient stress has hitherto been laid: (1) The importance of the cell-nucleus as an apparatus for storing up and giving out stimuli; (2) the possibility of the transference of stimuli between germ cells and somatic cells (or their nuclei) without any material connection whatever; and (3) the extension of what we

may perhaps call Herbert Spencer's principle of equilibration to the phenomena of heredity and development.

In order to develop the argument in a logical manner I propose to divide the subject matter into the following sections: --

- (1) The stimulating influence of the environment upon the individual organism, and the principle of direct equilibration between the organism and its environment.
- (2) The possibility of stimuli being stored up in the organism so as to produce after effects, and the inheritance of acquired characters.
- (3) The nature of the apparatus by which stimuli are stored within the organism, and the principle of equilibration between the cell and its nucleus.
- (4) The germ-cells viewed as store-houses of stimuli, and the principle of equilibration between the soma and the germ-cells.
- (5) The interpretation of ontogeny as a process of progressive equilibration, and the biogenetic law.
- (6) Amphimixis or sexual reproduction.

#### 1. THE STIMULATING INFLUENCE OF THE ENVIRONMENT UPON THE INDIVIDUAL ORGANISM AND THE PRINCIPLE OF DIRECT EQUILIBRATION.

It is perhaps hardly necessary to point out that any individual organism must be in a state of equilibrium with its environment and that any change in the environment may, if sufficiently long continued, act as a stimulus upon the organism and cause a definite response to be made by the latter. "Direct equilibration in organisms," says Herbert Spencer, "with all its accompanying structural alterations, is as certain as is that universal progress towards equilibrium of which it forms part."

Examples of such direct equilibration, or modification of the organism in accordance with change of environment, are familiar to every gardener. A hardy outdoor plant grown in a hothouse may altogether alter its habit of growth. Potatoes allowed to sprout in the dark send out shoots of quite a different character from those which are produced under normal circumstances. Certain Alpine plants which are especially adapted in their habit to the rigours of an Alpine climate, may be induced to change their mode of growth by simply removing them to sufficiently warm and sheltered situations, in which their habit approaches that of their lowland relatives.

These phenomena are more noticeable in plants than in animals because plants are constantly making new growth and it is chiefly in the development of new organs or parts that the stimulus of changed environment can produce the corresponding effect. In the

case of the Alpine plants above referred to, for example, leaves already fully formed at the time of removal will not be modified by the change of climate; it is the new leaves, formed subsequently to the removal, which will shew the adaptive modification. Organs when once fully formed tend to become fixed and incapable of responding in this manner to changed conditions of life.

Amongst adult animals, which have ceased to produce new growth, we see few conspicuous examples of such adaptive response to the stimulus of changed conditions. In some immature animals, however, it may be observed in a very striking manner; as, for example, in the case of tadpoles, which, when prevented from coming to the surface of the water by means of wire netting, will continue to develop as tadpoles instead of undergoing the normal metamorphosis into frogs.

As part of the direct action of the environment we may also conveniently include the Lamarckian principle of Use and Disuse as affecting the development of organs, for we must always remember that the body to a large extent constitutes its own environment, and that alterations in the mode of action of the different organs of the body may produce corresponding effects upon the structure of those organs.

It is not necessary for our argument to suppose that the stimulus of changed conditions of life always produces *adaptive* response on the part of the organism, though there is abundant evidence to shew that this is frequently the case, as in the Alpine plants and tadpoles referred to above, while those modifications which are unsuited to the environment will of course be weeded out by natural selection. For suggestions as to the *manner* in which the action of the environment may produce adaptive modifications in the individual organism, I may refer to the writings of Lamarck, Herbert Spencer, and Cope. "In animals therefore, as in plants," says Spencer, "the external mechanical actions to be resisted are themselves directly instrumental in working, in the tissues they fall upon, the changes which fit those tissues to meet them."

Cope gives very conclusive examples in the case of the formation of the joints of the vertebrate skeleton, from which he draws the following conclusions:—

"First. Continued excessive friction removes osseous tissue from the points of contact until complete adaption is accomplished and the friction is reduced to a normal minimum. Then a normal articular surface is produced.

"Second. Where the normal friction is wanting, and an inflammatory condition is maintained by a pulling stress on the investing synovial membrane, excess of osseous deposit is produced.

"Third. Stress on the articular ligaments and tendons stimulates osseous deposit at their insertions, which deposit may be continued into their substance. This is a pulling stress.

These observations, therefore, show that osseous deposit is produced by different forms of mechanical stimulus."

## 2. THE POSSIBILITY OF STIMULI BEING STORED UP IN THE ORGANISM SO AS TO PRODUCE AFTER-EFFECTS, AND THE INHERITANCE OF ACQUIRED CHARACTERS.

We may then take it as an established fact that the environment influences the individual organism in such a manner as to call forth modifications which in some cases at any rate are of an adaptive character, but it has been vehemently denied, by Weismann and his followers, that such modification, produced during the lifetime of the individual, can be handed on from one generation to the next; in other words, that "acquired characters" can be transmitted from parent to offspring.

In one of his earliest essays\* on this subject, Weismann observes: "The difficulty or the impossibility of rendering the transmission of acquired characters intelligible by an appeal to any known force has been often felt, but no one has hitherto attempted to cast doubts upon the very existence of such a form of heredity." . . . He then proceeds to evade the difficulty in question by denying the existence of the phenomenon to be explained:—"It has never been proved," he says, "that acquired characters are transmitted, and it has never been demonstrated that, without the aid of such transmission, the evolution of the organic world becomes unintelligible."† He also quotes‡ from Du Bois Reymond the statement that "the hereditary transmission of acquired characters remains an unintelligible hypothesis, which is only deduced from the facts which it attempts to explain."

Weismann's own theory of the continuity of the germ-plasm is, as is well known, an elaborate attempt to account for the phenomena of organic evolution without calling in the aid of the transmission of acquired characters, and he devotes an immense amount of ingenious argument to this object. "The understanding of the phenomena of heredity," he observes, "is only possible on the fundamental supposition of the continuity of the germ-plasm."§

It is impossible in the space at our disposal to follow Weismann in the laborious arguments by which he attempts to discredit the cases of transmission of acquired characters which have been brought forward in evidence against his own views, but it is of first importance in any discussion of the subject to be perfectly clear what Weismann himself means by an acquired character. "New characters," he points out, "may arise in various ways, by artificial or natural selection, by the spontaneous variations of the germ, or by the direct effects of external influences upon the body, including the use and disuse of parts. If we assume that these latter characters are transmitted, the further 'assumption of complicated relations between the

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\* Essays upon Heredity, English Translation, 1889, p. 80.

† *Cf cit.* p. 81.

‡ *Cf cit.* p. 82.

§ *Loc cit.* 104.

organs and the essential substance of the germ becomes necessary' (His), while the transmission of the other kinds of characters do not involve any theoretical difficulties."\* . . . "It is certainly necessary to have two terms which distinguish sharply between the two chief groups of characters—the primary characters which first appear in the body itself, and the secondary ones which owe their appearance to variations in the germ, however such variations may have arisen. We have hitherto been accustomed to call the former 'acquired characters,' but we might also call them 'somatogenic,' because they follow from the reaction of the *soma* under external influences; while all other characters might be contrasted as 'blastogenic,' because they include all those characters in the body which have arisen from changes in the germ. . . . We maintain that the 'somatogenic' characters cannot be transmitted, or rather, that those who assert that they can be transmitted must furnish the requisite proofs."†

These are amongst Weismann's earliest statements on the subject, and are taken from the only works of his to which I at present have access, my own library having not yet arrived from New Zealand, while this country appears unfortunately to be very badly supplied with biological literature.

As a definite and thoroughly well authenticated case of the inheritance of an acquired character I can quote the following from Cope's "Primary Factors of Organic Evolution":—

"A female (and very prolific) cat, when about half-grown, met with an accident. Her fine, long tail was trodden on, and had a compound fracture, two vertebrae being so displaced that they ever after formed a short off-set between the near and far end of the tail, leaving the two out of line. At first I noted that out of every litter of kittens some had a tail with a querl in it. With successive litters the deformity increased, until not a kitten of the old cat had a straight tail, and it grew worse in her progeny until now we have not a cat with a normal tail on the premises (in a cat-population of six or eight, exclusive of young kittens). The tails are now in fact mere stumps, some have a semi-circular sweep sideways, and some have the original querl. Perhaps the deformity was somewhat aggravated by in-and-in breeding and by artificial selection practised by my Chinaman, who, with the perversity of his race, preferred the crooked tails, and thus preserved them in preference to the normal kittens. There are no other abnormally-tailed cats in the neighbourhood."

"This is the essential part of an unpublished letter from that keen observer and eminent scientist, Professor Eugene W. Hilgard, of the University of California."

It is, of course, extremely unusual for mutilations to be inherited, and we ought rather to be surprised that there are any well-authenticated cases at all of such inheritance on record than that there are so few. No stimulus which has so short duration as part of the

\* *Cf. cit.*, p. 412.

† *Cf. cit.*, p. 413.

lifetime of an individual organism can be expected to make an impression on the germ-cells so deep and lasting as to manifest itself in a corresponding modification of the soma of the next generation. It probably takes very many generations of cumulative action to bring about such a result in ordinary cases, and the exceptional cases of immediate inheritance of conspicuous acquired characters must owe their origin to exceptional conditions of which we know nothing. If, however, the above quoted case is not an example of the transmission of a true "Somatogenic" or acquired character, it appears to me that such characters can have no existence at all, and that the whole argument is futile.

There is, also, another way of approaching the problem in addition to that of direct evidence. Weismann's primary difficulty, which led him to deny the transmission of acquired characters, appears to have been the difficulty of explaining the *modus operandi* of such transmission; if this difficulty can be overcome an important step will have been taken towards the solution of the problem.

It may be assumed that those who deny the inheritance of acquired characters mean that the characters in question will not appear in a second generation unless the stimulus which first evoked them is still operating, when, of course, the same effects may again be produced by the same causes. It is not difficult to demonstrate, however, that the environment may make a lasting impression upon the individual organism, which may continue to shew itself after the evoking stimulus has ceased to act.

Now, if we can thus shew that the living organism can not only respond immediately to the stimulus of changed environment, but can—if one may use the expression—store up such stimuli and be influenced by them long after the changed environment has ceased to operate directly, then it appears to me, we shall have good grounds for believing at any rate in the possibility of the inheritance of acquired characters.

As a matter of fact we have definite proof—in the existence of what are known as "after-effects" both in plants and animals—of the capacity of the individual organism for storing up stimuli which may subsequently produce a definite response.

The well-known daily periodicity of plant growth affords an illustration. The light of the sun acts as a check upon the rate of growth of ordinary plants, and it is easy to shew experimentally that in consequence of this action the normal plant grows most rapidly in the early hours of the morning after a prolonged exposure to darkness, and most slowly in the afternoon, after a long exposure to daylight. It has been shewn that this daily periodicity or variation in rate of growth in correspondence with the periodic variation in environment is continued when the plant is kept in perpetual darkness and the direct action of changing environment thereby rendered impossible.

A beautiful example of a similar phenomenon from the animal kingdom has been described by Dr. Gamble and Mr. Keeble

in the case of the shrimp-like crustacean *Hippolyte varians* of the British Coast. This animal adapts itself in a marvellous manner by colour changes to its environment, evidently for purposes of concealment, and, moreover, undergoes a periodical nocturnal and diurnal variation in colour. This periodical variation has been found to continue after the normal daily alternation between light and darkness has been artificially suspended.

Further examples of the same class of phenomena could easily be adduced, while, in the domain of psychology, the phenomena of memory may be regarded as affording another illustration of such after-effects, for we must regard these phenomena as being a kind of response to stimuli which were primarily exerted by the environment, and subsequently stored up in the brain for use on future occasions.

We thus see that the stimulus of changed environment may make such a deep impression upon the organism as to shew itself in "after-effects" when the original stimulus has ceased to operate. If one seeks for a purely physical analogy one can scarcely help calling to mind the phenomena of luminosity as exhibited by various substances which have the power of absorbing light rays when exposed to the light and emitting them again subsequently in darkness.

Judging from human experience in regard to memory the depth and permanence of the impression received by the organism from the environment will usually, depend upon the length of time for which the original stimulus was acting. The details of a walk which we have taken every day for a month are much more deeply and permanently impressed upon the memory—in other words, upon certain cells of the brain—than those of a walk which we have only taken once or a few times.

Thus we see that there appear to be two very distinct kinds of what we may call "memory"—a purely physical and unconscious memory, exhibited, for example, in the after-effects of daily periodicity, and a mental memory associated with consciousness; and though we may, for the sake of convenience, be allowed to speak of them as "two kinds," yet ultimately they are probably identical in nature, consisting in a storing up of stimuli by the organism, to be utilised on future occasions.

The plant-physiologist, Detmer, was, so far as I am aware, the first to call attention to the bearing of the remarkable phenomena of "after-effects" upon the theory of heredity. Weismann, in criticising Detmer's views, asks "what connection there is between these facts and the transmission of acquired characters."<sup>\*</sup>

"All these peculiarities produced by external influences," he says, "remain restricted to the individual in which they arose; most of them disappear comparatively soon, and long before the death of the individual. No example of the transmission of such a peculiarity is known."<sup>†</sup>

<sup>\*</sup> *Cf Cit.* p. 404.

<sup>†</sup> *Loc Cit.*

"After-effects are not transmitted, and compared with this fact but little importance can be attached to the use of vague analogies by Detmer, who would wish to conclude that heredity is only the after-effect of processes which had been set going in the parent organism."

The statement that "after-effects are not transmitted" seems to be an extremely rash one for a scientific man to make. It is proverbially difficult to prove a negative, and the experimental evidence at our command certainly cannot warrant such a wide generalization. On the other hand, it is no doubt equally impossible at present to prove experimentally that after-effects are transmitted. This is a point on which we may hope for experimental evidence in the future. In the meantime we must content ourselves with trying to answer the question whether there is any *à priori* reason why after-effects should not be inherited, or *vice versa*. We have seen already that stimuli may be stored up in the individual. We shall see later on that stimuli may be transferred from one cell to another without the transference of material particles, and therefore there appears to be no inherent improbability in the view that the stimuli which give rise to after-effects in the individual soma may also be transmitted to and stored up in the germ-cells, and give rise to after-effects in subsequent generations. This, of course, involves the supposition that the germ-cells are capable of being influenced by the soma, a belief which appears to me to admit of very little doubt. To this point we shall return later on.

### 3. THE NATURE OF THE APPARATUS BY WHICH STIMULI ARE STORED WITHIN THE ORGANISM AND THE PRINCIPLE OF EQUILIBRATION BETWEEN THE CELL AND ITS NUCLEUS.

Granting, then, as we safely may, that the organism has the power of storing up stimuli or impulses for future use, we are naturally led to enquire whether this function is generally distributed throughout the organism or is localised in definite centres.

This is a question which, owing to the imperfect state of our knowledge, can at present only be assumed in a tentative manner. One of the fundamental properties of living protoplasm is its capacity for responding to stimuli, or, in other words, its "irritability"; but the response, as when a muscle is stimulated by electric shock, or an *Amoeba* puts forth enveloping arms of protoplasm on coming in contact with a food particle, generally takes place immediately or after an extremely short interval, and ceases on the removal of the stimulus. Protoplasm, however, also exhibits so-called automatic movements, *i.e.*, movements which do not appear to be related to any stimulus external to itself, and there are grounds for believing that such movements are initiated and controlled by the cell-nucleus.

This belief is strongly supported by the phenomena of cell-division, in which the nucleus invariably takes the lead, and the general protoplasm of the cell follows afterwards. The unicellular *Amœba*, for example, consisting of a but slightly differentiated mass of cell-protoplasm (*Cytoplasm*), with a nucleus near the middle, reproduces itself by such cell-division. When the organism has attained a certain size the nucleus, consisting in large part of a special kind of protoplasm distinguished as the *chromatin substance*, divides into two parts which move away from one another. The surrounding cytoplasm then contracts into a narrow bridge between the two nuclei, and finally breaks across, and the division of the cell, in this case also an entire organism, is complete.

It has been shewn experimentally that an *Amœba* may also be made to multiply artificially by cutting it in pieces, and it is a fact of the highest significance with regard to the importance of the nucleus that it is only when a part of the nucleus is present in it that any particular fragment will live and grow.

In the developing egg of the higher animals and plants, again, the nucleus invariably takes the initiative, and the cell-protoplasm follows. Not only is this the case, but it has been shown experimentally, as Professor Minot observes, that in the Frog's egg "the position of the nucleus determines which part of the ovum shall become the dorsal surface of the embryo."

The structure of the cell-nucleus is, in reality, extremely complex, far more so than that of the surrounding cytoplasm, and in the vast majority of cases of cell-division a very elaborate re-arrangement of its constituent parts, known as "*karyokinesis*," may be observed. In this process certain parts of the nucleus known as the *chromosomes*, which have the form of longer or shorter threads, play a very important part, and though we by no means understand the full meaning of the phenomena in question, we are tolerably safe in believing with Weismann that one result of the karyokinetic process is to secure a very accurate qualitative as well as a quantitative division of the chromatin substance (chromosomes). During the process definite centres of force are established at opposite poles of the nucleus, to which the halves of the accurately divided chromosomes are attracted, one half of each chromosome being pulled towards each pole in a manner highly suggestive of magnetic attraction. In this process of nuclear division the membrane in which the nucleus is normally enclosed disappears, so that the general cell-protoplasm (*cytoplasm*) is no longer sharply divided from the nucleoplasm between the chromosomes, while the common protoplasmic mass thus formed exhibits strong lines of radiation around the polar "spheres of attraction." Ultimately the general protoplasm of the cell divides into two parts, which arrange themselves around the two groups of chromosomes, and the cytoplasm is again shut off from the nucleoplasm by the formation of a new nuclear membrane.

The almost if not quite universal occurrence of a nucleus, or at any rate of chromatin substance, within the cell-body, even in the

lowest organisms, indicates that the division of the cell substance into chromatin and cytoplasm is of fundamental importance. According to our view the meaning of this division is to be found in the necessity for a differentiation of the cell into two parts, one external (the cell-body), which responds freely to external stimuli (when suitably placed), and one internally (the nucleus), which is but slowly, and probably through the intermediation of the cell-body, affected by external stimuli, but which, when once so affected, stores up these stimuli for a longer or shorter period, and is capable of giving them out again after the original external stimulus has ceased to operate.

Just as there must be an equilibration between the entire organism and its environment, so there must also be some kind of equilibration between the cell-body and its nucleus. The cell-body is then acted upon by two sets of forces, the external forces of its environment on the one hand and the internal forces of the nucleus on the other. The forces which we imagine to be stored up within the nucleus to a certain extent control the behaviour of the cell-body and prevent it from altogether changing its characters with every change of environment. Thus we have in the nucleus a complex apparatus by means of which we may perhaps explain the production of "after-effects."

In the course of ordinary cell-division the elaborate processes of karyokinesis may be supposed to secure the division of the nuclear material into two halves of equal dynamic value, about each of which the cytoplasm will arrange itself in the same way because each requires the same form of cell-body to equilibrate it.

We find a simple illustration of the equilibration between the cell and its nucleus in the case of the well-known springing monad -- *Heteromita*. This organism consists of a pear-shaped mass of protoplasm enclosing a nucleus and provided with two whip-like extensions of the protoplasm, or flagella, whose contractions enable it to move about in the water. One of these flagella projects forwards from the pointed end of the body, the other is attached to the lower surface. In common with other unicellular organisms *Heteromita* sometimes reproduces by simple cell-division or fission, and this fission may take place either transversely--across the body--or longitudinally--in the length of the body. It is as usual accompanied by division of the nucleus. When fission takes place transversely it is obvious that the body of the cell must be divided into totally dissimilar halves, one with an anterior flagellum and one without. The ventral flagellum simply splits into two, one of which remains attached to each of the daughter-cells, but no possible division of the anterior flagellum could provide both of the new cells with such a structure. What actually happens is that one of the daughter-cells keeps the old anterior flagellum while the other develops an entirely new one from what was the posterior extremity of the parent.

These phenomena may readily be explained on the principle of equilibration between the cell and its nucleus, and, so far as I can

see, in no other way. We may suppose that the original nucleus divides into two halves of precisely equal dynamical value, each of which, therefore, requires the same form of cell-body to equilibrate it, and the only way in which this equilibration can be attained is by the development (amongst other things) of a new flagellum by one of the daughter cells. In other words, the nucleus exercises a definite controlling force over the cell-body of such a character as to evoke a definite response in the form of structural modification.

We have here a simple case of heredity, and, as I believe, one of inheritance of acquired characters. There can be little doubt that the evolution of the flagella in *Heteromita* was due in the first instance to the direct action of the environment. We know how readily in *Amoeba* temporary pseudopodia are emitted when the protoplasm is appropriately stimulated, and the transition from pseudopodia to flagella is a perfectly gradual one. At first temporary, these organs gradually became by more and more frequent use permanent structures. Their development must have disturbed the pre-existing balance of forces between the cell-body and its nucleus, but as it probably took place very gradually, the process extending over many generations, this disturbance was not sufficient to produce disruption, and the forces in the nucleus became slowly re-arranged in equilibrium with the changing structure of the cell-body. Thus in turn the nucleus acquired a new potentiality, a tendency to compel the cell-body to produce a flagellum in order to equilibrate its own stored up forces. In other words, the development of a flagellum by the cell-body acts as a stimulus upon the nucleus, and this stimulus is stored up in the nucleus and given out again subsequently to the cell-body, inducing the latter to develop a flagellum when necessary to restore the equilibrium between cell and nucleus. Thus in time the production of the flagellum comes to partake of the nature of an after-effect which may take place independently of the environment.

It may be urged that the development of the new anterior flagellum by the young *Heteromita* is due solely to that same action of the environment which originally called forth the flagellum in the ancestors of the race. The action of the environment, so long as the conditions remained the same, would certainly tend to produce the same effect in each generation, but the conditions do not remain exactly the same, for the new flagellum appears before its possessor commences to lead an independent life. Moreover, it always appears in such a definite fixed position and with such rapidity and precision that we cannot believe that it is evoked *de novo* by the action of the environment in the development of each individual. In the higher animals, again, there are many characters which appear regularly in the development of the individual, and which no longer have any relation whatever to the nature of the environment; such, for example, are the gill-slits in the neck of the embryo chick, and these can be due only to the action of internal forces.

#### 4. THE GERM-CELLS VIEWED AS STORE-HOUSES OF STIMULI, AND THE PRINCIPLE OF EQUILIBRATION BETWEEN THE SOMA AND THE GERM-CELLS.

The higher animals and plants differ from such lowly organised forms as *Amaba* and *Heteromita* in that the body is composed of a number of cells instead of a single one, and this number is usually very large. The majority of these cells become specialised in various directions to form the various tissues of which the body is composed, and may, therefore, be distinguished as *somatic* or body forming cells. A certain number, however, remain unspecialised, and form the germ-cells. These retain to a large extent the characters of primitive unicellular organisms (*Protozoa*), and are alone capable (in most cases) of separating themselves from the organism, and giving rise by a process of cell-division and progressive differentiation to a new individual of the same kind as the parent.

Admitting, with Weismann and others, that the nucleus of the germ-cell is the seat of the hereditary tendencies which mould the new organism into the form of the parent, the question arises: "How do these hereditary tendencies, or latent stimuli, come to be stored up in the nucleus of the germ-cell?"

Darwin, we know, imagined the existence of minute "gemmules" which were supposed to migrate from all parts of the body to the germ-cells, there to be stored up until required later on to control the development of the new organism. Weismann, on the other hand, supposed that the hereditary tendencies were located in certain minute bodies which he called determinants, and that these determinants were present in the germ-cells so to speak *ab initio*, being handed on from generation to generation by the continuity of the germ-plasm. He further maintained that the germ-cells are separated from the somatic cells at an extremely early date, and that they cannot be influenced by the surrounding body or soma, with the necessary corollary that somatogenic characters, acquired in the lifetime of the individual, cannot be transmitted to the next generation. This point we have already had occasion to discuss, and we need only point out here that Weismann's theory in this respect is directly opposed to that of Herbert Spencer, as expressed in the following paragraph:—

"It is an unquestionable deduction from the persistence of force that in every individual organism each new incident force must work its equivalent of change; and that where it is a constant or recurrent force the limit of the change it works must be an adaptation of structure such as opposes to the new outer force an equal inner force. The only thing open to question is, whether such readjustment is inheritable; and further consideration will, I think, show that to say it is not inheritable is indirectly to say that force does not persist. If all parts of an organism have their functions co-ordinated into a moving equilibrium, such that every part perpetually influences

all other parts, and cannot be changed without initiating changes in all other parts—if the limit of change is the establishment of a complete harmony among the movements, molecular and other, of all parts; then among other parts that are modified, molecularly or otherwise, must be those which cast off the germs of new organisms. The molecules of their produced germs must tend ever to conform the motions of their components, and, therefore, the arrangements of their components, to the molecular forces of the organism as a whole; and if this aggregate of molecular forces is modified in its distribution by a local change of structure, the molecules of the germs must be gradually changed in the motions and arrangements of their components, until they are readjusted to the aggregate of molecular forces. For to hold that the moving equilibrium of an organism may be altered without altering the movements going on in a particular part of it is to hold that these movements will not be affected by the altered distribution of forces; and to hold this is to deny the persistence of force.\*\*

We may readily admit with Weismann and his school the continuity of the germ-plasm from generation to generation, and we certainly grant the immense importance of the chromosomes in heredity, but still there appears to be no valid reason yet brought forward for denying the influence of the body upon the germ-cells, although this influence may require a long period of time to make itself felt. Nor is there any reason for supposing, with Darwin, that a migration of material particles is necessary in order to ensure that the germ-cells shall be able to reproduce the body in all its details in the process of development.

In the inorganic world the recently discovered phenomena of wireless telegraphy shew clearly enough how complex forces may be transmitted from one centre to another at a distance without any material connection, and it is not difficult to shew that a living cell may influence another at a distance without either organic connection or the transfer of material particles.

A good illustration of this transference of stimuli from one cell to another at a distance is afforded by the fresh-water alga *Spirogyra*†. This little plant occurs in the form of tangled masses of slender green threads, each thread being composed of a single row of cylindrical cells placed end to end, and each cell being enclosed in a firm wall of transparent cellulose. At certain times a process of sexual reproduction takes place, commencing with a conjugation between the cells of two filaments which happen to be lying side by side and parallel with one another. One of these filaments may be regarded as male and the other as female, and the process appears to be inaugurated by the cells of the male filament. Each of these which happens to have a cell in the other filament opposite to it puts forth

\* Principles of Biology. Vol. II., p. 387.

† Attention has already been called to this case, e.g., by Professor H. B. Orr, in his interesting and suggestive work on "Development and Heredity"; but I am not aware that anyone has hitherto demonstrated the inadequacy of the chemiotactic theory which has been adduced in explanation of the facts.

a hollow protuberance of the cell wall; this is met by a corresponding protuberance from the female cell, and the two projections unite to form an open canal through which the protoplasm of the male cell migrates to the female cell. It sometimes happens, however, owing to inequality in the sizes of the cells, that there may be a cell in one filament which lies between two cells of the other filament, and which can find no mate. In this case the solitary cell remains quiescent, and exhibits few or none of those remarkable activities which characterise the conjugating cells on either side of it.\*

Here it is obvious that in the case of two cells lying opposite to one another, though not in contact, and though each is enclosed in a firm cell-wall, some stimulus is transmitted from one to the other which calls forth a definite response in the formation of the connecting canals and subsequent phenomena. It might perhaps be (and, indeed, actually has been) argued that the stimulating effect is due to the secretion of some chemical substance by the cells in question, as has been shewn to be the case in the attraction of the spermatozooids to the archegonia of ferns, but this chemiotactic explanation appears to be quite insufficient in view of the important fact that cells which have no mate do not form gametes and may undergo no change, though also apparently exposed to the influence of any chemical substances in the surrounding water.

If, then, one cell can stimulate another at a distance without any material connection whatever, it would seem that there is no great improbability involved in supposing that every cell of the animal or vegetable body, at least in its earlier stages of development, before it has become too specialised, may be more or less influenced by every other cell in the body which is not too much specialised, as well as directly or indirectly by the external environment. Any modification of one part of the body, involving a disturbance of the internal equilibrium, may naturally be expected to produce some corresponding modification in the germ-cells, and perhaps also in other parts of the body itself, and this may be the clue to the explanation of correlated variations.

When, of course, as in the higher animals, an elaborate nervous system is developed, the influence of one part of the body upon another is greatly facilitated—we have, to use our physical analogy, a system of telegraphy with wires supplementing, and perhaps to some extent supplanting, a system of telegraphy without. But in the lower organisms, and in the early stages of development of all organisms, there is no nervous system, and in such cases we must suppose that the internal equilibrium is maintained either by forces acting at a distance without material connections or through the medium of undifferentiated protoplasm.

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\* I say, "few or none," because it occasionally happens that two cells may compete with one another for a mate; but, as far as my own observations go, only one is successful, and the other never gets even as far as the breaking up of the spiral chromatophore preparations to the formation of the gamete, though a more or less developed protuberance of the cell-wall may be formed, and may even be met by a corresponding protuberance from the opposite cell-wall.

A striking illustration of the manner in which the equilibration between the constituent cells of the body is maintained is afforded by the experiments of Hans Driesch and others upon developing eggs. To quote from Professor Minot:—"The egg of a sea-urchin divides into two cells, each of which multiplies and normally gives rise to half of the body of the animal. By somewhat violent shaking the two cells may be artificially separated; each cell may then develop into a complete larval sea-urchin, but of half the normal size only. Similar experiments have since been made by other investigators, who have obtained like results with other animals, vertebrate as well as invertebrate. Even more remarkable larvæ have been raised from blastomeres of the four-cell and eight-cell stages of segmentation, producing larvæ of one-fourth and one-eighth the normal size."

Now, if each blastomere when isolated from its fellows develops into a complete larval animal, why does it not do so when it remains in contact with its fellows? It can be only the mutual influence of the blastomeres upon one another which determines what part each shall play in the development at this early stage. By virtue of the karyokinetic process we may suppose that the first division of the nucleus of the egg results in the formation of two centres of control of equal dynamic value, each, therefore, requiring the same form of cell-body to equilibrate it. If the blastomeres are separated from one another each will divide again in the same way because it has the same dynamic value. If, however, they remain in contact, as they normally do, the dynamic value of each is modified by the presence of the other, and they will behave accordingly. The ultimate form of the multicellular body to which they give rise will be the resultant of the forces exerted by all the blastomeres and their nuclei as they continue to divide, modified to some extent, no doubt, by the physical environment.

Thus it is that each artificially separated blastomere gives rise to a complete but diminutive larva, the same result being attained by the action of identical forces in each case, and this being the only result which can equilibrate the forces at work.

It may be urged that the difference in behaviour between an isolated blastomere and one which remains in contact with its fellows is due to mechanical causes, such as pressure, etc., in other words, that it may be external and not internal forces which determine the behaviour of the blastomeres. To some extent no doubt this is true, but this in no way affects the proposition that the forces, presumably centred in the nuclei of the blastomeres, require at every successive stage of development a certain definite form and arrangement of the blastomeres to equilibrate them. Moreover, a different type of arrangement is characteristic of different types of organisms, which proves conclusively that internal as well as external forces are concerned in producing the result. At any rate we see clearly that when the equilibrium existing between the constituent cells or blastomeres of an embryo is upset by separating them, it may be restored again

by the formation of fresh cell-combinations of the same kind as existed in the original embryo.

The phenomena of regeneration of lost parts in animals and the striking of roots by cuttings in the case of plants are only more complex illustrations of the manner in which a disturbance of the equilibrium of an organism—whether between the constituent parts of the organism itself or between the organism and its environment—is remedied by re-arrangements which result in the old form being again produced. We must suppose that the unbalanced forces remaining over after the disturbance act as stimuli, which evoke structural modifications of whatever character may be necessary to restore the equilibrium.

Any cell of the body is originally potentially a germ-cell, but the great majority of the cells lose the power of developing into new organisms in becoming specialised to meet the requirements of their special environment, including under that term the surrounding cells of the body. The extent to which this power may be preserved, however, by ordinary somatic cells is very well shewn in the case of the *Begonia* leaf, cells of which have the power of giving rise to new and complete plants.

It appears to be an invariable rule, however, at any rate in all the higher animals, that special germ-cells are set apart at a very early stage in the development of the organism for the sole purpose of reproducing the species. These cells are especially distinguished by their undifferentiated character. Whereas the somatic cells become variously specialised in accordance with their varied functions, some as muscle cells, others as nerve cells, and so on, the germ-cells do not become specialised for any somatic function, but are so situated as to be protected as much as possible from the influences of the environment, and thus hindered from specialisation. There is no reason, however, to suppose that they are so far removed from the influence of the somatic cells as to be prevented from receiving and storing up stimuli which they may subsequently give out again under appropriate conditions. We have already seen reason to believe that stimuli may be transmitted from cell to cell without the aid of material particles and without the aid of protoplasmic connection, while the phenomena of after-effects have taught us that stimuli may be stored up by living protoplasm for future use.

In accordance with the principle of internal equilibration the forces stored in the germ-cells must be in a state of equilibrium with all the forces exerted by the body—the body and the germ-cells must balance one another.

We may suppose that up to the time of their maturation the germ-cells are in a receptive condition, capable of receiving and storing stimuli from the surrounding soma.

In the process of maturation we know that the germ-cells undergo very curious changes, and there is reason to believe that in the female cell at any rate a portion of the nucleus is cast out. The ovum also commonly becomes invested in a vitelline membrane, while the spermatozoon acquires a vibratile tail. In other words,

the germ-cells usually become specialised at length for special functions concerned with their union, and with this specialisation they may be supposed to lose the power which they have hitherto possessed of receiving and storing up stimuli, of which they have already received the full complement requisite for controlling the development of the new organism to which they will give rise.

### 5. THE INTERPRETATION OF ONTOGENY AS A PROCESS OF PROGRESSIVE EQUILIBRATION AND THE BIO-GENETIC LAW.

Leaving out of the question for the present the complications introduced by the sexual process, we must now enquire how the processes of ontogeny or individual development may be explained in accordance with the above enunciated views as to the nature of the germ-cells and their relations to the somatic or body-cells.

The fertilized ovum, or egg-cell, at the time of commencing its development, consists of a certain amount of protoplasm, often charged with food material, and containing a nucleus in which we suppose to be stored up ancestral stimuli which will control the development. Let us imagine these stimuli to be given out again in the order in which they were received.

The first stage in the development of a typical organism is the division of the ovum into two cells, preceded, of course, as always, by division of the nucleus. This two-celled body must make, and must always have made since it was first developed, its quatum of impression upon the nuclei, must produce, that is to say, probably within the nuclei, a system of forces which requires a two-celled body to equilibrate it.

This system of forces constitutes a stimulus which is stored up in the nuclei, and handed on by nuclear division to the future germ-cells, and this will be the first stimulus given out by the nucleus of the developing ovum. Therefore, the developing ovum will divide into two cells exactly in the same way as its ancestors did, this being the only way in which equilibrium can be attained.

But although the two-celled body may have been at one time a more or less permanent condition, it is now only temporary, and is rapidly succeeded by a four-celled stage, and this also must always have made and must still make its impression upon the arrangement of forces in the nuclei, and so on, through all the different stages of development with their increasing complexity of structure. At every successive stage of development the stimuli stored up in the nuclei must give rise, by internal equilibration, to a form of body similar to that which originally transmitted these stimuli to the nuclei, and which is the only form which can balance these particular forces.

Why, it may be asked, should we suppose that the stored up stimuli in the nuclei of the developing organism must always be

given out again in the order in which they were received? A moment's reflection will shew that each successive stage in development is the necessary antecedent of those which come after it. We cannot, for example, have an eight-celled stage before a four-celled, and so on. Every stage is strictly dependent upon and conditioned by that which immediately precedes it. Each stage, in fact, forms an important part of the complex stimulus which calls forth the next stage, and the whole development is a process of progressive equilibration. The germ-cell will, therefore, commence its development by dividing into two parts exactly as its ancestors did, and so long as all the conditions remain the same the subsequent stages of the ontogeny must all be identical with the ancestral stages, and must yield an identical result. Thus, when a given sequence has once been formed it must be repeated in the same way so long as the environment remains constant, and the problem of ontogeny resolves itself into the question: Why has organic evolution taken place at all, and why have not all organisms remained in the condition of simple primordial cells? or, looking at the question from a slightly different point of view, we may ask, what is the origin of those latent forces in the germ-cell which determine its development into a particular species of plant or animal?

The answer to these questions appears to be that every time the process of ontogeny is repeated the conditions under which it takes place may be slightly different from what they were before, and the developing organism makes a definite response to the stimulus of the changed environment. Structural modifications are thus produced in the individual by direct equilibration, or, in other words, new characters are acquired.

It is obvious that, so long as the changed conditions are maintained these structural modifications must repeat themselves in each succeeding generation, because the same causes will produce the same effects, and in this way not only may new stages be added to the end of the ontogeny but earlier stages may be modified, as we see in the production of larval organs, etc.

Suppose now that the changed environment returns to its earlier condition, so that the stimuli which called forth the new characters cease to operate. Will those new characters immediately disappear or will they persist for a longer or shorter period? We know they do not necessarily disappear in the lifetime of the individual, but will they be present in the next generation? A particular environmental stimulus may have been operating for, say, a thousand generations, during each of which it has produced the same effect in the ontogeny of some organism. Are we to suppose that if that stimulus is suddenly removed the effect in question will at once cease to show itself? This is what those who maintain the non-inheritance of acquired characters would have us believe. We prefer to believe, and we have already given reasons for so doing, that during the time for which the stimulus in question has been producing structural modifications in the body by direct equilibration,

these modifications have in their turn been influencing the germ-cells by internal equilibration, and that the germ-cells will store up the stimuli which they receive so as to be capable of producing a kind of after-effect upon the developing organisms even after the original external stimulus has been completely removed. The amount of this after-effect, if we may so term it, will be proportional to the length of time for which the original stimulus acted.

We cannot, therefore, as we have already observed, expect a character which has been acquired in a single generation, and has had little time to influence the germ-cells, to make a sufficiently deep impression upon them to secure its own transmission as an after-effect, and hence the scarcity of evidence for the transmission of acquired characters, although, as we have already seen, there are exceptional cases in which suddenly acquired characters make such a deep impression upon the germ-cells as to be transmitted to the next generation. It is, however, to quote the words of Darwin, "generally necessary that an organism should be exposed during several generations to changed conditions or habits, in order that any modification thus acquired should appear in the offspring."\*)

The development of a complex organism may then be looked upon as consisting mainly of a series of superposed after-effects, which continue to shew themselves long after the originating stimuli have been removed.

The various stages in the ontogeny are also probably deeply fixed by mere repetition, for the more frequent the occurrence of any particular somatic condition the deeper will be the impression which it makes upon the germ-cells and the more difficult will it be to remove that impression.

This method of looking upon the ontogeny or life history of an individual as a series of after-effects, first suggested by Detmer, is, as far as I can see, the only rational way of explaining the Biogenetic Law, or, as it is sometimes termed, the Law of Recapitulation, in accordance with which organisms tend to repeat, in their own development, the ancestral history or phylogeny of the species to which they belong.

#### (6). AMPHIMIXIS OR SEXUAL REPRODUCTION.

The phenomena of heredity are usually greatly complicated by the process of sexual reproduction or amphimixis. This consists essentially in the union or conjugation of two germ-cells, usually derived from separate individuals, to form a third cell known as the *zygote*, which develops into a new individual.

It has been shewn that the essence of this process of conjugation lies in the union of the so-called pronuclei of the male and female gametes or germ-cells within the protoplasmic body of the

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\* Animals and Plants under Domestication, Vol. II., p. 389.

zygote; another fact which points to the extreme importance of the nucleus. Thus the developing organism comes to be controlled by stimuli which are derived from two parents and which will differ according to the nature of the environment to which those parents and their ancestors have been exposed.

Two separate store-houses of ancestral stimuli, and therefore two separate centres of control, meet together in the zygote, and there are various possibilities as to the manner in which they will share between them the work of controlling, by progressive equilibration, the developing organism:—

- (1) The male and female centres of control may be able to blend their forces intimately in the so-called segmentation nucleus, and the developing organism will then be controlled by the resultant, and may be expected to exhibit characters more or less intermediate between those of the two parents. This appears to be the most usual condition of things and it is to such cases that Galton's law of inheritance applies, viz.: "That the two parents contribute between them on the average one-half, or  $(0.5)$  of the total heritage of the offspring; the four grandparents, one-quarter, or  $(0.5)^2$ ; the eight great-grandparents, one eighth, or  $(0.5)^3$  and so on. Then the sum of the ancestral contributions is expressed by the series

$$\frac{1}{2} \{ (0.5) + (0.5)^2 + (0.5)^3, \&c. \},$$

which, being equal to 1, accounts for the whole heritage."

- (2) The male and female controlling centres may be incapable of blending their forces; in this case they may separate completely at the first or at some subsequent division of the segmentation nucleus, and thereafter each may control a certain fraction of the developing organism, yielding a lopsided result. This is probably the explanation of those remarkable abnormal insects mentioned by Darwin, in which one half or one quarter of the body is like that of the male and the other half or three quarters like that of the female.\* Such cases are, however, extremely rare and only occur by way of abnormality.
- (3) The male and female centres of control may remain for one or more generations associated in the same nuclei (though one may completely dominate over the other in its influence upon the developing organism); but they become dissociated sooner or later on the formation of new germ-cells (gametes), the gametes bearing the different types of nuclei respectively being produced on an average in equal numbers. To this category must be referred those cases described by Mendel and Bateson in which the offspring of a cross gradually separate themselves out in definite numerical proportions.

In these latter cases we must suppose that there is in the first instance only an incomplete amalgamation of the male and female pronuclei, the differential characters being sufficient to prevent perfect

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\* Animals and Plants under Domestication, Vol. II., p. 394.

union, and that later on, when new germ-cells are separated from the soma, the descendants of the original male and female chromosomes separate out from one another and form pure germ-nuclei.

The Mendelian cases, and also those mentioned under the second heading, may be regarded as intermediate between cases of complete sterility (due to total want of amalgamation between the male and female pronuclei owing to excessive differences) and cases of complete amphimixis or sexual union (due to successful co-operation of the male and female pronuclei).

It appears then that in cases where the ancestral stimuli stored up in the male and female pronuclei exhibit too great differences, it will be impossible for these pronuclei to unite in one segmentation nucleus for the control of the developing organism. The sterility of distinct species when crossed is thus probably due to the confusion and disruption of the systems of forces in the pronuclei of the germ-cells by antagonizing ancestral stimuli.

Here also, it appears to me, is to be found the explanation of the well-known fact that crossing frequently leads to reversion. When two individuals are crossed together which are varietally or even specifically distinct from one another, but not too distinct to be fertile together, the offspring very frequently 'reverts' to some ancestral condition, as, for example, in the classical instance of the production of the ancestral blue rock pigeon by crossing of distinct domesticated races. Here we may suppose that the very different characters of the immediate ancestors of the mongrel (represented in the germ-cells by stored stimuli), tend to cancel one another, while the closely similar or identical characters derived from more remote ancestors (also represented in the germ-cells by stored stimuli but usually over-mastered by more recently acquired stimuli) tend to augment one another, with the result that ancestral characters appear in the offspring while more recently acquired characters are absent.

According to Weismann and his school amphimixis is to be regarded as a process whereby variations are produced by the permutation and combination of characters derived from two distinct lines of ancestry. These variations form the material upon which natural selection operates.

According to our view sexual reproduction is by no means necessary for the production of variations, which are due primarily to the influence of the environment. Indeed it seems more reasonable to suppose that the result secured by sexual reproduction is that of checking excessive modification and preventing the organism from becoming too specialised and stereotyped. If a species or variety loses the power of adapting itself to its environment it is liable to extermination when that environment changes. The power of adaptation may be lost by over-specialisation in any one direction, and this over-specialisation is checked by amphimixis, which must tend to maintain the average characters of a species in equilibrium with the average characters of the environment.

Darwin himself appears to have held a very similar, if not identical view as to the meaning of sexual reproduction, for he observes: "When species are rendered highly variable by changed conditions of life, the free intercrossing of the varying individuals tends to keep each form fitted for its proper place in nature."<sup>\*</sup>)

We may also notice that long before Darwin wrote these words Lamarck, in favour of whose views on the subject of organic evolution there is now such a strong reaction, had made a closely similar observation, viz.: "In reproductive unions the crossings between the individuals which have different qualities or forms are necessarily opposed to the continuous propagation of these qualities and these forms. We see that in man, who is exposed to so many diverse circumstances which exert an influence on him, the qualities or the accidental defects which he has been in the way of acquiring, are thus prevented from being preserved and propagated by generation."<sup>†</sup>

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<sup>\*</sup> *Animals and Plants under Domestication*, Vol. II., p. 355.

<sup>†</sup> Lamarck, *His Life and Work*, by A. S. Packard, p. 310.

## SECTION C.

### 29.—PRESIDENTIAL ADDRESS.

BY SIR CHARLES METCALFE, BART., M.I.C.E.

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“Wherever and by whatever means sound learning and useful knowledge are advanced, there to us are friends. Whoever is privileged to step beyond his fellows on the road to scientific discovery will receive our applause, and if need be, our help. Welcoming and joining in the labour of all, we shall keep our place among those who clear the roads and remove the obstacles from the paths of science, and whatever be our own success in the rich fields which lie before us, however little we may now know, we shall prove that in this our day we knew at least the value of knowledge, and joined heart and hands in the endeavour to promote it.” These were the closing words of Mr. John Philipps, the President of the British Association when he delivered his Address at the meeting held at Birmingham in 1865, and they well and fitly convey the aim, the scope, and the spirit of the South African Association of Science which has just been inaugurated, and of which this is the first meeting.

The aim of the Guilds and Societies of the Middle Ages was to guard their trade secrets, to conceal their methods of production; the broader-minded spirit of the 20th century is to spread the knowledge of every new discovery likely to tend to the further increase and economy of production and to publish the best methods of organisation, so as to arrive at getting the best results at the lowest cost. It is owing to the magnanimous way in which rival firms and rival nations competing for trade and markets are generally glad and willing to show their methods to each other, as well as to the now recognised value of research; and to the enormously increased means of communication throughout the world that improvements have been made so rapidly in the last few years in every branch of manufacture. The aim of our Association is to foster the vitality of scientific research, and to disseminate its result, so to encourage economical production, and to do our share to increase the resources and wealth of South Africa.

Not many years ago there was a division, a barrier, between those who claimed to be scientific men and those who called themselves practical. The latter reckoned that they had always got on well enough without so-called science, and believed that their share in the world's work was the most important, whereas scientific men looked upon themselves as a class apart. We are now getting beyond that stage, and we recognise the importance and the necessity of the work both of the chemist and his laboratory, and of the business man who applies and utilises the knowledge of nature. If we here duly understand the value of the intimate relations between science and

applied art it should lead to such a rapid development as this world has never seen before. Even in European countries, where vested interests are strong, where vast amounts of money have been expended in manufactures which are now not up to date, and in processes that are being rapidly superseded, there has been a considerable quickening of spirit in the last few years, and there is a general wish to set the house in order. How much more, then, should we in South Africa with the opportunity afforded by the latest knowledge, with the open veld to build on, and living in a country with such enormous mineral resources of iron, coal, and copper, besides its wealth of gold and diamonds, and the possibilities of agriculture, duly improved by irrigation, resolve that, as far as in us lies, South Africa shall take her stand amongst the foremost nations of the earth. The keynote of this century is intensity of labour; it can scarcely be said to be the motto of all in South Africa to-day, but with increased competition there is no reason, climatic or otherwise, why labour should not be as strenuous here as in America, and even to-day many men work as hard here as in any country in the world. One of the prominent questions of immediate interest is

#### IRRIGATION.

Mr. Willcocks, in his able report on this subject for South Africa, suggested that all rivers and torrents should be proclaimed as public domain, the property of the Government representing the people, as was done by Victor Emmanuel in Italy; whether this is possible or not is not a matter for discussion here, but this is certain, that some legislative measure dealing with irrigation is necessary before much can be done in the way of large irrigation schemes, except in rare and isolated cases where all the riparian owners are of one mind. Without proper legislation we shall continue to see millions of cubic feet of flood water roll away uselessly, and what might be a source of wealth to thousands of farmers wasted every year. The great factor of course in successful irrigation work is common-sense; it is of no use making irrigation works at a cost that makes each area irrigated so costly that it will not pay to work, nor is it economically wise to irrigate more area than you can possibly get cultivation for. The two great instances where successful irrigation works have been carried out on a large scale are in India and Egypt; in both these countries the inhabitants have cultivated the soil for many centuries. In India 23 million pounds sterling have been expended by the British Government on vast irrigation works providing water for the irrigation of upwards of 13 million acres, that is, at a cost of about 35s. per acre. In Egypt the great works which have just been completed have cost probably £10 per acre or more, but as this land when irrigated is worth never less than £30 per acre, and often considerably more, the work is economically well justified. It is interesting to see how we are ruled by sentiment even

in such engineering enterprises. The Temples of Philae are Roman, not Egyptian, and are not more than two thousand years old, comparatively recent, therefore, beside the old Egyptian Temples. The Assouan Dam, which cost over two millions of money, has raised the level of the water so that Philae is now half submerged, and the water raised to this height provides water sufficient to irrigate four hundred thousand acres. By spending £500,000 more in raising the height of the dam, instead of four hundred thousand acres, it is estimated that one million six hundred thousand acres would have been irrigated, but as this would involve the demolition or removal of Philae, it was not allowed, so that probably some five million pounds annually has been lost to Egypt because of sentiment.

### RAINFALL.

Any means of getting increased rainfall should be welcome to the inhabitants of this country; careful observation over a long period of years seems to show that forest soils absorb more and evaporate less than soil in the open, that forests tend to moderate the extremes of climate and to increase rainfall, and that the nearer we approach the Equator the greater is the effect of vegetation on rainfall. There has been great waste of timber in this country. In Pondoland the natives were in the habit of setting fire to magnificent forest trees merely to grow mealies to better effect where the trees had been, and there is not a trace now left of trees where a few years ago there was not only bush but fine timber, too. Fertile soils disappear with the destruction of forests, and the accumulation of years is washed away, another instance of waste. Forestry, then, has an important bearing on the material wealth of a country apart from the value of the timber. This has been to some extent recognised in the Cape Colony, and money has been spent in proper plantations on scientific lines; and it is hoped that all the sleepers for the Cape Government Railways may be procurable from the plantations that have been and are being made. On the railways in the United Kingdom the annual consumption of sleepers for renewals is about 3,750,000 a year at a cost of about £750,000 a year. The cost of renewals in the Cape Colony is probably at least a tenth of this sum, or £75,000, of which probably half should be saved on this account alone by the local supply, besides the benefit to the climate and the advantage of the employment given to those working the forests. A large amount of timber, too, is required by the Mines of South Africa for mining props and other uses, suitable timber for which can be grown in this country. Another probable source of demand for timber will be for the paving of the streets in towns, thereby adding to the comfort and health of the inhabitants. For road paving, wood is undoubtedly the material which the public likes best; it is comparatively noiseless, and is not so slippery as asphalt. The so-called Teak forests of Rhodesia may possibly provide wood for this purpose, and in any case "Jarrah" and other suitable woods for street paving can be

grown in South Africa, and, if grown in sufficient quantity, could be exported to England with advantage, forming an additional item of return freight.

Return freight for ships is one of the crying needs of this country, and every effort should be made to increase the tonnage of freight back to England, and so cheapen the cost of freight out to South Africa. The amount conveyed annually by sea to South African ports has increased enormously in the last few years. Besides imports from other countries the latest statistics show that the exports from the United Kingdom to this country have increased three-fold in the last ten years. It is a notable fact that South Africa imports more now from England than any other country except India, and taken per head of the population more than any other country in the world. In 1902 British exports to South Africa were valued at £25,690,611, to India, whose population may be estimated at about 294 millions of people, goods to the value of £30,109,628, to the United States £23,725,971, to Germany £22,852,252, to Australia £19,560,502, and to France £15,712,516. South Africa, then, with a population, white and coloured, say, of  $4\frac{1}{2}$  millions, purchased in 1902 to the extent of £5.14 per head. Considering this great increase in tonnage, it is to be hoped that freight vessels of larger size will soon be the rule rather than the exception. The propelling power required for a vessel for a given speed increases in a slower ratio than the increase of its displacement, so that there is a great resulting economy in using large vessels at a moderate speed. For freight purposes there is probably no vessel so economical as a nine thousand ton boat with a speed of eleven knots, provided that it can fill up with cargo without undue delay; and considering the figures of the imports into South Africa and the purchasing power of South Africa, there should be no difficulty in running boats of this tonnage. Is it too much to hope that faster passenger boats may before long make the passage between Southampton and Cape Town in a fortnight? The twin-screw steamer "Oceanic," of 17,274 tons gross and 6,917 tons net, the "Celtic," of 21,900 tons gross and 13,449 tons net, make the passage between Liverpool and New York, about half the distance between Southampton and Cape Town, in seven and eight days respectively. The Cunard Company now propose to build two fast steamers, and the German vessel now building, the "Kaiser Wilhelm II., is to have a speed of 24 knots, to carry 1,800 passengers, and to burn 750 tons of coal a day, whereas the steamship "Cedric," now building, to carry 3,000 passengers, is to have a speed of 17 knots, and will burn only 260 tons of coal a day. There seems, except in South Eastern Russia, a hesitation in starting generally with oil as fuel for ships in spite of the fact that bulk for bulk oil will develop twice the power of coal, thereby affording more room for cargo, and that oil does away with the necessity of having stokers, saving probably 80 or 90 men on a steamer. The limits of size of ships have not yet been reached, and provision should be made for the larger vessels of the future, and accommodation should be provided in all new harbour work for vessels of 1,000

feet in length with a draught of 35 to 40 feet. Here in Cape Town Harbour, which should have been one of the finest harbours in the world, we have an object picture of want of foresight and tinkering for present needs, but there is hope in the fact that those now in authority have recognised the inadequacy of the present accommodation, and are prepared with a scheme of proper scope. In every fast growing country it is necessary to lay out a scheme providing for very great expansion, and with a fitting sense of economy to carry out from time to time only such portions of that scheme as are warranted by the probable trade of the immediate future.

When it is remembered that at the old established port of Liverpool, in Lancashire, the rate-paying tonnage of vessels increased from 6,089,543 tons in 1875 to 10,021,725 tons in 1900, there is good reason in anticipating a much larger percentage of growth in a country that is in the first stage of development. The handling of tonnage on a large scale, especially dealing with coal, ore, or grain, has led to the use of very special electric cranes of the gantry or cantilever class. The "Brown Hoisting Machinery Company," of Cleveland, Ohio, has erected machines on the Great American Lakes which handle nearly 20 million tons a year, and have brought the cost of handling down to an extraordinarily low figure. The "Temperley Transporter Company," in the United Kingdom, has done excellent work in providing transporting and hoisting plant, and special apparatus for unloading barges into trucks or into warehouses, and in Germany ingenious coal conveying plants have been erected by the "Benrathe Maschinen Fabrik," and the "Allgemeine Electricitäts Gessellschaft," of Berlin. For working cranes electricity seems to possess advantages over steam or hydraulic cranes, or cranes worked by compressed air. The ideal crane should start its load slowly, accelerate to a high speed, and slow down quickly to a standstill. The electric crane meets these requirements better than any other. The further advantages of electric cranes are: (1) That the power consumed is proportional to the work, (2) and that the power can be conveyed to a greater distance more easily and at a cheaper cost than by another means; (3) the electric crane has a total efficiency of 72 per cent., whereas the efficiency of hydraulic cranes is rarely more than 50 per cent. The special systems of transportation alluded to have hardly been wanted here as yet, as they are only economically used when a large tonnage has to be handled for a short distance with great speed and at a low cost. At the Diamond Mines the problem is to mine the blue at the lowest cost, to haul it to the surface from a total depth of 1,200 to 1,500 feet (and we may note that 600 tons of blue are hauled daily up one shaft) to carry it thence by endless haulage to the floors on the open veld, where it is exposed to weather and disintegration, and from thence to transport it after weeks of exposure to the washing machines, and thence to the pulsating machines, where the diamonds are caught and separated by grease and other special contrivances. An interesting development is taking place now at the De Beers Mines, where a central electric power station is being erected with all the ad-

vantage of all the latest development of mechanical skill. The gold mines have had the benefit of the advice and supervision of the best mining engineers, consequently all appliances are up to date, and there has been a great advance in the knowledge of cyanide working. The problem there of the immediate future is as to the best methods of working, and knowledge of hoisting ore from depths than has up to now been attempted in mining; we may look forward shortly to the time when those who wish to take up mining as their profession will go to learn their lessons at the Rand.

### COAL.

The requirements of the mines have resulted in the opening up of portions of the great coal deposits of the country, and it is worthy of notice that whilst the cost of coal mining varies considerably, coal is now produced at one or two mines in the Transvaal for four shillings a ton at the pit's mouth, which compares favourably with anything achieved in Europe, though it is not so cheap as in some of the Pennsylvanian Coal Mines, where it is said to be put on trucks for a total cost of 2s. 6d. per ton.

The coal production of the world is estimated to be about 800 million tons, of which the United States produces about 260 million tons, the United Kingdom about 230 millions, and Germany 150 millions.

Science and Chemistry have achieved important results in the last few years, first, in reducing waste, and, secondly, in utilizing the by-products in all manufactures, notably in the manufacture of coke in the ovens of the Otto Hoffmann, and the Bauer, Breuer and Brunck, and later the Otto-Hilgenstock types, which are everywhere superseding gradually the old wasteful beehive oven. In these new ovens the coal shut up in close retorts and exposed to a high temperature gives in addition to the coke the following by-products, viz.: tar, gas-liquor, from which by distillation sulphate of ammonia is obtained, largely used, especially in Germany, as a soil fertilizer or manure, and coal gas containing benzol. Attempts are now being made to utilize the waste heat of blast furnaces; the importance of this is shown by the fact that although the by-product gas of the blast furnaces in the Cleveland Iron District in England has been successfully used for years in heating the hot blast stoves, and for raising steam, yet there is still a waste of some 61,000 horse-power in the gases, and Mr. Whitwell goes on to say that the further waste of heat in the iron and slag is equal to 276,140 tons of coal, or 31,500 horse-power, making a total power going to waste of 92,500 horse-power in that district alone every year.

Many attempts have been made to utilize the slag by grinding it for mortar, making paving blocks of it, and using it as a fertiliser, but the commercial result has not been very successful so far. Perhaps it may be the good fortune of this country to produce metallurgists and engineers who will solve this problem.

There are vast deposits of iron in South Africa unworked except

by the Kafirs. Let us hope that a change may come, and come quickly, and that we may ourselves see Iron and Steel Manufactories established in this country.

Our knowledge of metals and their alloys has been much added to by microscopical research. Chemical analysis can give us the components of an alloy, or the percentage of materials in a sample of steel, but experience has taught us that the behaviour of a metal under mechanical tests may vary very considerably, although its chemical composition, as shown by chemical analysis, may remain the same, and it is here that microscopic research is so valuable.

One of the lessons we have learnt is the necessity of standardisation both of tests and of sections and sizes of iron and steel. In America, Germany, France, and now in England quite recently, standard sections have been adopted. The producer thereby can cheapen production, because he can roll the different standard sections, knowing that he can place the surplus to stock, and the purchaser knows that he can buy these standard sections at a low cost. Care must be taken that elasticity and expansion of idea are allowed for, and that standardization does not spell fossilization or check progress. The cheapening of steel and iron will mean perhaps more to South Africa than to most countries, for not only will there be here an enormous demand for rails, bridges, galvanized iron and fencing, structural steel, for high buildings and warehouses, and all the other steel and iron ware, but there is in South Africa no construction timber grown, that is, the timber most largely consumed in engineering work, and in buildings, and as such wood gets dearer and dearer, and steel work gets cheaper, there will come a time, perhaps in the near future, when steel and iron will be used, perhaps fortified with concrete, in the construction not only of tall structures and giant edifices, but in dwelling houses and cottages, instead of timber. The cheapening of aluminium has extended its use in ways unthought of a few years back. Who would have ventured a few years ago to say that aluminium would be used for the frames of carriages, or as an alternative to copper wire for electric power transmission? It is our duty to be ever on the alert to take advantage of the constant changes that take place and to utilize fresh materials and new methods, that from the fluctuation of prices become from time to time the most economical and the best for our purpose.

We have had an instance of this in the growing use of the "Otto Hoffmann" and "Otto Hilgenstock" Ovens. Another important instance is the start now made in the use of gas engines supplied by producer and water gas. Six years ago there was no general use for these, because the gas used was exclusively made from expensive coal or coke. But in 1897 "Mond" erected a producer using soft coal slack, which was inexpensive. These gases, such as "Mond's" or "Dowson's" water gas, have a very low illuminating power, and their calorific power is only a third or a fourth of that of ordinary illuminating gas, yet, as they can be used at a cost of about 3d. or 2d. per 1,000 cubic feet, it seems likely that the large

gas engine, as certain difficulties attending it are gradually combated with and overcome, will supersede the steam engine for land purposes.

Great progress has been made in gas engines recently. In 1900 the first gas engines above 400 h.p. were started running with Mond gas. In the same year at the Paris Exhibition the 600 h.p. Cockerill gas engine was exhibited. Since then Messrs. Korting Bros. have made a large number, of which in September last 32, with a total of 44,500 h.p., averaged 1,390 h.p. each. The John Cockerill Company has built one of 2,500 h.p., and the Snow Steam Pump Works of Buffalo, New York, have just made two large gas engines, gas compressors of 4,000 h.p. each.

The internal combustion engine has found a great field in small power engines in small yachts, torpedo boats, and in automobiles. Motor cars may still be said to be in their infancy, and much time, money, and research will have to be expended on them before they become as reliable as commercial machines should and must be, but there is an enormous field before them. The haulage of heavy loads along the roads is becoming every day more of a necessity. Motor wagons can carry larger quantities and heavier amounts of goods at a higher speed than is possible by horsed vehicles; they take up less room in the streets, and the damage to the road surface should be less than that caused by the ordinary traction engines. The motor omnibus has certainly not yet reached the stage which some predict for it, viz., that it will supersede the electric tramway. The motor carriage that will never break down, and that can be purchased at a price within the means of all those who can afford a horsed carriage is still a thing of the future. Automobile petrol inspectors' cars are already running on some of the railways in this country. On railways, too, there may be a great future for automobiles. They are being tried at the present moment on one or two of the railways in England, and by the Gardner Serpolet Company in France. For suburban traffic, where thousands come to their work in a city in the morning, and make a return journey mid-day for their meal, and return to their homes in the afternoon, large numbers have to be conveyed within a very short period at certain times of the day, whereas during the rest of the day the traffic is much less, and trains at ten minutes or fifteen minutes interval will accommodate it. Hitherto electric traction has generally been proposed to meet the case. There is, however, a hesitation on the part of railway authorities generally in incurring the heavy cost of electric installation, and it is rather a moot point whether there is any saving in working cost, although the increased accommodation is a benefit to the public. The multiple unit system by which one, three, five, or more cars can be despatched at a time all under the control of one conductor gives just that elasticity of accommodation that is wanted to deal with the daily variations of suburban traffic. If this system is adaptable to motor cars which is the subject of enquiry at the moment, there may be a great development of the automobile for suburban railways. There is no costly installation, nothing has to be changed on the

present railways, it is merely a question of providing the motor carriages. A train that can equally well take a thousand passengers as fifty seems just to meet the problem of dealing with congested traffic at certain times of the day, and a limited number of passengers for the rest of the day. For Tubes and Metropolitan Railways where the traffic is so great throughout the whole of the day that it requires a train, say, every three minutes all day long to accommodate it, electrical working is the cheapest, but it is quite probable that where a less frequent service during most of the day will meet the wants of the public, and there is merely a congestion at certain times, the automobile may prove the most economical. In a new country electricity is readily adopted. It is fortunate for us, perhaps, that electricity has advanced as it has, and reached the stage of standardization in dynamos, transformers, and cables, before we were ready to take advantage of it to any extent. In electric lighting some economy may result from the "Cooper Hewitt" lamp, which gives an efficiency of about three candles per watt, but this light at present is of too ghastly a colour to be popular. If you look at your neighbour by it, you see only dingy, yellow, and dirty purple in the complexion. It is a long glass vacuum tube about 5 feet long and an inch in diameter, with a bulb of mercury in the bottom. The electric current passing through gives out this light by the radiation of the mercury vapour. No doubt some method of improving the colour of this light will be found. Acetylene will under certain conditions be found to be cheaper than electric light, and it is claimed for Kitson's new petroleum incandescent lamp that streets can be lighted by it at one-fourth the price of electric light. The electric furnace is useful for melting glass, and possibly silica for optical and laboratory purposes. In the electric furnace the temperature is limited only by the volatilization of the electrodes, that is to say, temperatures, and consequently chemical actions are possible in the electric furnace which cannot otherwise be attained. Here, too, we are only on the threshold, so to speak. M. Harmet, Manager of the St. Etienne Iron and Steel Works, has designed an electric furnace for producing finished steel from raw iron ore. This furnace consists, first, of a calcinator, in which the oxides or other matters charged in the raw are dried, roasted, and calcined; secondly, a reducer, in which is effected the reduction of the oxides; and thirdly, the regulator where the metal which comes liquid from the reducer is finished. M. Harmet claims to make a saving of 16s. 8d. per ton by his process.

In various parts of South Africa there are great possibilities of utilizing the water-power of falls, notably at the Victoria Falls on the Zambesi, one of the sights of the world which has not been visited by more than 200 white people since the world began. The supply of water-power throughout the world is almost always greater than the demand. At Niagara I believe only 110,000 h.p. are utilized out of  $4\frac{1}{2}$  millions available. At Victoria Falls, with perhaps double the horse-power of Niagara, it may be a long time before we use as much. The advantages of water-power are its cheapness and its

certainly. It does not depend on the fluctuating price of coal, and it is independent of labour, but, on the other hand, we have to recognise the fact that the power required for many manufactories is only a small part of the cost of production.

Up to the present electro-metallurgical processes have taken the most advantage of cheap water-power. Aluminium, phosphorus, carbonium, soda and chlorine, cyanide of potassium, electro-deposition of copper, electro-fusion process, calcium carbide, and the manufacture of flax fibre represent part of the field of activity near water-power. In many cases, as waterfalls are not where they are wanted commercially, against the cheap water-power must be put the extra carriage for materials, and coal, and the cost of carriage of the manufactured article from the Fall to where it is to be used. Luckily, in the case of the Victoria Falls coal of a very good quality is close at hand in the "Wankie" coal field, and any manufactured product will have the advantage of down freights.

The long distance transmission of electric power has increased from year to year, and for the past twelve months power has been delivered from the "Yuba" Falls at Colgate, California, to Stockton, a distance of 216 miles. There is no difficulty now in the transmission. The question always is whether the power delivered, allowing for leakage, can be used commercially, that is, economically, as compared with any other motive power.

Electricity as applied to agriculture is still in its infancy. In Germany power has been supplied from central power stations to farmers for threshing corn, but the use of motor ploughs, motor harrows, and motor hay-making machines has hardly commenced. When water-power comes to be utilized for agricultural purposes, the possibilities are immense. The cotton crop of the United States is over  $1\frac{1}{2}$  million tons annually, worth 55 million pounds, while the maize grown averages 40 million tons. For both maize and cotton the fertile country round the Victoria Falls is well suited, and if electricity can be applied successfully to their culture there is a chance of very cheap production there of these two important crops.

The railways of South Africa have been built under various conditions, but generally not until there was an outcry from some more or less flourishing centre, but it is now recognized that they can be made the pioneers of development, provided that they are constructed on commonsense lines. Where the traffic is large the line should be thoroughly well built to carry that traffic in the most economical and expeditious manner; where the traffic only warrants one or two trains a week the line should be laid down so as to allow for future expansion of trade, but constructed on the most economical lines, so that even with the small traffic it may have a chance of paying its way. There is nothing new in this; it was done in America, it has been done in New South Wales and other countries, and it is the best way of opening up a country of large distances but sparse population.

The cost of construction of railways in South Africa compares favourably with that of other countries under similar conditions. Some 6,000 miles of railways have been built in South Africa, and arrangements have been made to expend some 10 millions of money on new lines. It is a great pity that the original gauge laid down from Cape Town to Wellington of 4 feet 8½ inches was altered to the present gauge of 3 feet 6 inches. There is no divine right in any particular gauge, but for passenger traffic, especially over long distances, a certain width of carriage is necessary to accommodate the human frame. The passenger coaches, therefore, on the 3 feet 6 inches gauge, which is the standard gauge of South Africa, are as wide as they are on the wider gauge of Europe and America. The overhang, therefore, is very much greater, and partly owing to this fact, and partly to the smaller locomotive wheel possible on the 3 feet 6 inches gauge, the speed of passenger trains in South Africa is about half that general on broader gauge lines. The inconvenience has not been much felt as yet, but as the public becomes more and more addicted to travel, as it assuredly will do, the feeling against the present standard gauge of South Africa will become intensified. This is still a young country, but it will grow very fast; now, therefore, is the time to insist that the best possible education should be obtainable. The employer of labour as well as the employee requires the best education that can be devised, and by education is meant the cultivation of the natural powers and talents of the child and the man so as to fit him to do his work and occupy his place worthily as a member of society and a citizen.

#### TECHNICAL EDUCATION.

"We do amiss to spend seven or eight years merely in scraping together so much miserable Latin and Greek as might be learned otherwise easily and delightfully in one year." So wrote the classic Milton nearly two hundred and sixty years ago, but the same process still continues in England, and it is only very recently that, pressed by the competition of other countries, a feeling that all is not right in the matter of education has arisen. Commissions have been appointed to report on foreign educational systems, such as those of Germany and Holland. There is a general uneasiness all round, and some change now seems likely to take place. The question of education is of vital importance, especially the question of so-called secondary education.

The report of the Special Sub-Committee of the London Technical Education Board on the application of Science to Industry in August last, stated that various branches of industry had during the past twenty or thirty years been lost to England owing to the competition of foreign countries, and that these losses were to be attributed in no small degree to the superior scientific education provided in foreign countries, especially in regard to the transfer from England to Germany of numerous departments of manufacturing

chemistry, as instanced by the manufacture of aniline dyes and many other valuable products, coal-tar, the manufacture of pottery of the finer kinds, and the manufacture of optical glass, all owing in a great measure to the deficiency of the educational system in England. Summing up the evidence the Committee stated that they were convinced that the main cause of our relative failure in the chemical and optical industries were:—

1. The lack of scientific training of the manufacturers themselves, and their consequent inability to recognise the importance of scientific assistance.
2. The defective condition of our secondary education.
3. The lack of a sufficient supply of young men trained in scientific principles and methods, and the application of science to particular industrial processes.
4. The lack of any Institution providing advanced technological training which is sufficiently endowed to enable it to give an equal attention to poor graduates and varied work.

The Committee further stated that the curriculum has been so hampered by the exigencies of examining authorities, and examinations, that the teacher had been compelled to devote undue attention to storing the minds of the students with facts for reproduction, at the expense of the time which should be devoted to stimulating their reflective powers, and making them think. The cause of the want of vitality in our scientific industries is due to the defect in secondary education and the lack of adequate provision for training and research.

The diplomatic and consular reports published from time to time by the Foreign Office estimate the whole value of German chemical industries at not less than fifty millions sterling per annum, and that these have sprung up chiefly in the last thirty years, and that they are largely founded upon basic discoveries made by English chemists, and that the reason they were not taken advantage of in England was due to the want of education among our so called educated classes, and also among the workmen upon whom those depend. The terms of this report must cause serious reflection—the whole of our system of education wants correction. Too much stress is laid upon mechanical memory and the answer of preconcerted questions. The first thing should be to encourage the child's power of observation and of forming judgments, to teach him to get to the bottom of things and never to be satisfied with superficial knowledge and the mere answering of parrot questions; care should be taken. To ground him in sound knowledge of principles and habits of careful exactness in his work, then to develop independent thought and action, by which he can later further advance his knowledge in any special branch, having made himself acquainted with the most detailed information available of the particular profession he is about to take up. All that can be done in the educational institution is to impart a thorough grounding in the principles of science and their logical application. The specialization must come later. All the

educational institution can do is to fit the student so as to take up the practical work as efficiently as possible. Employers in engineering industries are always willing to accept from trained students a shorter apprenticeship than is asked in the case of untrained men. Men who have had a sound preliminary training take less time than the uneducated man to acquire the practical knowledge, since they have learned how to think and apply such knowledge as they have. The whole subject is full of difficulty, there is so much to learn and so short a time to learn it in. Many parents cannot afford to let their children have so many years schooling as others can; but the importance of education is fully recognized in South Africa, let us see that such education shall be the best obtainable, and the best adapted to the needs of this country.

For Mining students at any rate it is hoped that the establishment of technical schools at Johannesburg will supply the advantage of acquiring knowledge on the soundest basis with the opportunity of becoming acquainted with the latest methods and practice at the mines.

This is a great country in the course of making, it teems with problems which will need all the wisdom of the wisest, all the honesty of the most upright; let us who are the heirs of the Ages do our utmost by the mutual co-operation of scientific workers, to extend the boundaries of knowledge, to take our part in moulding public opinion, and to influence for good for all time the progress and development of South Africa.

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connection with the great social question of the rural population. If the loss of this goes forward at the present rate, the Empire must fall to pieces for want of recruits for the Army. In Germany it is estimated that the yearly wages of the people employed on forest industries amount to something like £30,000,000 sterling, and that roughly 12 per cent. of the total population of Germany is employed in the forest and out of the forest. About 1,000,000 people in the forest, i.e., directly employed in working the forest estates, and about 3,000,000 out of the forest, i.e., in working the forest produce, chiefly timber, into the various articles manufactured from wood. These forest workers in Germany are the pick of its manhood, the backbone of the nation. In England they have been replaced by the weakly, hysterical, knock-kneed factory operative, and his sickly tea-drinking wife, whose mistaken ambition is to avoid the health and strength following manual labour out-of-doors! These are sad facts which struck me very forcibly when travelling through the forests of the Continent and the rural districts of England. It was not till I got to Scotland that I saw a woman working out-of-doors. In the first part of the Boer war, out of 11,000 men offering themselves as recruits in the Manchester district 8,000 were found to be physically unfit to carry a rifle "and of the 3,000 who were accepted, only about 1,200 attained the moderate standard of muscular power and chest measurement required by the military authorities." (R. E. Dudgeon, M.D.) England can better afford to pay the cost of its wasted forests, viz., £20,000,000 a year, than allow the present waste of its manhood to proceed!

Not only is there a loss of non-production within the British Isles, but the cost of importation by sea of so bulky a material as timber is naturally very heavy. To produce within the British Isles the timber now imported would require an area of about nine million acres of forest, that is to say, one acre of forest to  $8\frac{1}{2}$  acres of open country. This would amount to on an average about  $1\frac{1}{2}$  "New Forests" to every county. Germany as we have seen has one acre of forest to every 4 acres of open country. Cape Colony spends £60,000 per year on its Forestry, or about one per cent of its average revenue. If England were to reforest at the same rate £1,000,000 yearly would represent the forest expenditure, and about two-thirds of a county the area of restored country. France spends over half a million yearly on Forestry.

According to the report of the recent Commission on British Forestry there are 21,000,000 acres of heather and rough pasturage in England and Scotland available for reforesting; 8,000,000 acres of forest would produce the timber now imported. It is calculated that if all the waste lands of Great Britain and Ireland were reforested the production of timber (excluding a small proportion of hardwoods) would be 3 or 4 times the timber now imported. (National Forestry in Jour. Soc. of Arts, Nov., 1899.)

There is one redeeming feature in the present sad position of Forestry in England. Since the doom of English Forestry was sealed in Henry VIII's time it has not been possible to restore artificially

the National Forests, at a remunerative rate. When I was a boy it was necessary to pay 5% for money on good security. Forests in Europe have not returned hitherto more than  $2\frac{1}{2}$  or 3%. It is only within the last fifteen or twenty years that money could be borrowed at a sufficiently low rate of interest to make the restoration of the forests remuneratively possible.

### FORESTS OF CAPE COLONY.

The total area of indigenous forests in Cape Colony, from Cape Town to Natal, is estimated at 500,000 acres, or 810 square miles. Of this all but an estimated area of about 30,000 acres is Government forest worked systematically by the Forest Department. This is but a small percentage of the total area of the Colony, rather less in fact than  $\frac{1}{2}$  per cent. Small though this area is, if it were well stocked it would be enough to supply the country's present wants and leave a good margin for export; but unfortunately the forest area is but poorly stocked with commercial timber. The yield of the Indigenous forest in its present poorly stocked state is estimated at only from 6 to 10 cubic feet per acre per year. This may be compared with the yield of European forests from 50 to 150 cubic feet, or with the yield in Eucalypt plantations which ranges up to 700 cubic feet per acre per year. The following is a selection of actual forest yields from Eucalypt and Pine plantations in Cape Colony.

#### YIELD IN CUBIC FEET PER ACRE PER YEAR OF TIMBER PLANTATIONS IN CAPE COLONY.

	Cubic feet.
Tokai: Kari (Prince Kasteel) ... ..	625.
" " (Cedar ridge) ... ..	533.
" Eucalyptus saligna (Sphinx rock) $\frac{1}{4}$ Acre: 18 years old in 1900 ... ..	527.
Worcester: Euc. globulus (Copse first 5 years) ... ..	457.
Tokai: Kari (Manor House Ridge) ... ..	377.
Plumstead: Cluster pine (14 years old) ... ..	341.
Worcester: Euc. globulus (1st crop over the whole 60 acres) ... ..	332.
Ceres Road (sample area Euc. globulus) ... ..	322.
Newlands: Cluster pine (G. 93. 52. Heywood) ... ..	178.
" " " (Heywood & Brown) ... ..	170.

An inspection of these figures brings out the curious fact that as much timber can be got in one year from a good Eucalypt plantation, as during 100 years in the indigenous forest—the "rotation," or lifetime of the forest (so to speak) from seed-time to harvest.

#### EXHAUSTION OF COAL-FIELDS MET BY FUEL PLANTATIONS.

This high rate of production has a general interest outside the production of timber. As I showed recently ("Nature," March 20th,

1902) it furnishes one of the most convenient and practical means of fixing and utilizing the sun's energy. The fixation of carbon, in a quick growing Eucalypt or Wattle plantation in South Africa, is about fifteen times that of a similar plantation in Europe. To-day, near Cape Town, it is less costly to plow the ground and produce wood fuel in a plantation of Wattles or Gums than to import coal fuel oversea, or by a long journey overland. If, on the World's surface, we take latitudes below  $40^{\circ}$  and rainfalls above 40 inches, and imagine this covered with forest, either with tropical forest or the quick-growing Eucalypt and Acacia forest of the extra-tropics, I calculated that there could be produced yearly, at the lowest computation, thirty times the world's present consumption of coal! Details of this calculation are given in one of the forest pamphlets which are on the table for distribution.

#### CAPE COLONY'S TIMBER BILL AND THE MEANS TAKEN TO MEET IT.

During 1902 the imports of timber to Cape Colony amounted in round numbers to half a million pounds sterling. Previous to the war the average for some years was a quarter of a million. South Africa is a poor dry country. It cannot afford to go on sending these enormous sums out of the country to pay for foreign wood, hence the existence of Forestry at the Cape. In its Forestry Cape Colony now stands at the head of every British community. Speaking recently Dr. Schlich (who occupies at this moment the position of the highest authority on forest matters amongst Englishmen) stated that amongst the British Colonies and dependencies, only India and Cape Colony had seriously considered the forest question. India is a tropical country with vast areas of poorly stocked pestiferous forests and a comparatively small area of well-stocked, healthy extra-tropical forest on the Himalayas. For some years past Cape Colony has spent, on an average, £60,000 yearly on Forestry. Of this amount between £40,000 and £50,000 is spent on timber plantations, composed mainly of Eucalypts and Pines. The bulk of the Eucalypt planting is to produce sleepers for the Railways. The Cape Government Railways require annually about one million cubic feet of timber and literally train loads of imported sleepers, mostly Jarrah, can be seen now by any traveller on the Cape Railways. These Jarrah sleepers come from West Australia and cost at the rate of 5/- per sleeper delivered here. The Cape Government Railways have now to spend nearly £100,000 yearly for imported sleepers. It is thus a matter of great importance to produce this timber at home, especially when it is considered that we have an exact duplication here of the climate of Australia, where these Eucalypt sleepers are produced. *Eucalyptus marginata*, or Jarrah, is the sleeper now most in favour. Some time back metal sleepers were used, but these have turned out as unsatisfactory here as in most other places where they have been tried; and the creosoted pine sleepers require the extra expense of a plate to prevent them being cut into by the heavy rails and rolling

stock they now have to carry. There are immense areas of Jarrah and Kari timber in Western Australia, in nearly pure forest, near the coast, so that access is easy and supplies assured. Kari timber is more suitable for use above ground than in the ground, but Jarrah has a well-established reputation for lasting in the ground; and there is, I think, no doubt that few better sleepers can be obtained than the Jarrah sleepers of Western Australia. East Australia is naturally fitted to produce equal or rather better sleepers. The Iron-bark timbers of Eastern Australia are harder and even more durable than Jarrah, and there are some half dozen other Eucalypt timbers equal to Jarrah in durability. But East Australia is comparatively an old settled country. It is 100 years since the British Colonists set to work destroying the forests; and to-day, East Australia cannot supply Iron-bark sleepers under 6s. or 6s. 6d. landed here. The unique Cedar-wood of East Australia, *Cedrela toona*, is also mostly destroyed; and so great and so utterly reckless has been the destruction of forest in East Australia that even the luxuriant Black-wattle has now become scarce. Not many months ago an enquiry actually came from Australia, to the Natal Black-wattle plantations, asking at what price bark could be shipped to Australia! The Black-wattle tree came not very long ago from Australia to South Africa, and the Natal plantations are entirely the work of the last few years. However, to return to our sleepers. The Cape Government Railways lately decided to lay down special sleeper plantations, for which purpose sites have been chosen near existing lines of railway, so as to avoid the heavy cost of transport to the railway. The financial position of these railway plantations is very striking. It is estimated that they will cost £60,000 or £70,000, and in 20 or 25 years will bring in a *perpetual revenue of £100,000 per annum*. This is calculated on the basis of the present mileage of Cape Railways and the prices paid for sleepers. The species of Eucalypts that I have selected for sleeper plantations are the following:—

#### EUCALYPTS FOR SLEEPER PLANTATIONS.

- (1) *E. paniculata*; an Ironbark.
- (2) *E. pilularis*; Flintwood.
- (3) *E. microcorys*; Tallow-wood.
- (4) *E. resinifera*; a Jarrah-like timber.
- (5) *E. saligna*; Quick-growing good timber.  
(*E. marginata*; Jarrah, low yield.)

These timbers are equal or superior to Jarrah, and they are more fast growing.

#### SOFT-WOOD FOR SLEEPERS AND HOUSE BUILDING.

In spite of the fact that Soft-wood sleepers require the extra cost of a bearing plate and of creosoting, they are now being produced largely, especially in plantations where the poor nature of the soil is unadapted to the rapid growth of Eucalypts. The species which

is almost exclusively used for these plantations is Cluster-pine (*Pinus pinaster*). This is a tree which has become completely naturalized in the South-west of Cape Colony, and which, by means of plantations, is spreading elsewhere in South Africa. Cluster-pine is largely used for sleepers in the South of France and the North of Spain. It is so hardy and grows so vigorously along the Southern Coast of South Africa that Mr. J. S. Gamble (author of the classical work on Indian timbers) is of opinion that it should be given the preference to Gums in sleeper plantations. It is spreading self-sown up the crags of Table Mountain, and out over the sands of the Cape Flats. The Cape Forest Department uses about twelve tons of Cluster-pine seed yearly in its re-foresting operations. So far, it is free from any serious pests, insect or fungoid. From its great enemy, fire, it is protected by cutting up the pine plantations, like a chess-board, with protective strips of Eucalypts. These Eucalypt fire-lines are productive instead of being a source of expense, and are more effective in arresting sparks than the usual cleared or plowed fire-lines.

The other pines that have grown largely enough to be now considered naturalized are:—

*Pinus insignis*, or Insignis pine.

*Pinus halepensis*, or Jerusalem pine.

*Pinus canariensis*, or Canary Island pine.

*Pinus pinca*.—The Stone-pine, or Umbrella-pine, of Italy, has been grown at the Cape for 150 years or more; apparently it was introduced before the Cluster-pine. But about 25 years ago it was attacked by a fungoid disease—*Peronospera* sp.—and has now ceased to have any importance as a forest tree. *Pinus insignis* suffers from a variety of diseases; it can no longer with safety be planted in large masses, for which purpose its place may be taken by its home associate *Pinus muricata*. The beauty and rapid growth of the Insignis pine will, however, ensure its continued planting as an ornamental tree.

The four Pitch-pines of the Gulf States of the United States of America are being planted with caution. They are climatically suited only to the wettest parts of the Southern coast. They are:—

*Pinus australis*,

.. *mitis*,

.. *cubensis*,

.. *taeda*.

#### OTHER TREES.

Besides the Eucalypts and Pines a great variety of other trees are being planted in Cape Colony. It would take too long even to enumerate these. The Cedars alone would require a paper to themselves to describe. About twenty-five species yielding Cedar or Cedar-like wood are under cultivation. These are absolutely the most valuable timbers grown in South Africa, but they have not the economic importance of the Eucalypts and Pines on account of their slow growth. These trees

belong to the genera *Juniperus*, *Cupressus*, *Callitris*, *Cedrella*, and *Cedrus*. Cape Cedar, the most useful of the indigenous timbers, is *Callitris arborea*. It grows on the rugged Cedarberg Range 100 miles North of Cape Town, to the size and stature of the Cedar of the Atlas Mountains; but, alas, the former extensive Cedar Forests of Cape Colony were ravaged, by axe and fire, for 150 years before the Forest Department came into existence, and only vestiges of these valuable trees now remain. Unlike the delicate trees of the evergreen Indigenous forest, Cape Cedar is perfectly hardy against wind, drought, frost, and snow; it seeds abundantly, and is easily propagated.

Other interesting timber trees now being planted are the Blackwood, *Acacia melanoxylon*, and the Camphor. Blackwood has a timber like walnut; and Camphor the scented wood yielding the Camphor of commerce.

Of ornamental trees we may mention the Pepper-tree, *Schinus molle*, which flourishes in the dry inland districts; the brilliant scarlet flowering Gum, *Eucalyptus ficifolia*, on the coast districts; the noble English Oak, which is here more a fruit tree than a timber; and the Plane, with its dense foliage flourishing, like the Weeping-willow, near water.

The Government timber plantations, which are mostly near Cape Town, or in the mountains North of King William's Town, now embrace about 20,000 acres of timber, and they are now manufacturing timber for the country at the rate of about three million cubic feet yearly. This is above one-third our present timber importation,  $7\frac{1}{2}$  million cubic feet, or more than half of what we were importing before the war, 5 million cubic feet. None but it has been used for pit props, and the thinnings supply already a great deal of firewood. Indeed, one of the oldest of the plantations near Cape Town keeps a sawmill constantly at work sawing up firewood, and the revenue from the sale of firewood and young plants in these plantations now equals the expenditure, before cutting a stick of the main timber crop! This is a most satisfactory result.

There are, as mentioned, up to date, about 20,000 acres of fully stocked timber plantations in Cape Colony. One of the oldest and best known of these plantations is at Tokai,  $1\frac{1}{2}$  hours from Cape Town. I was absent from Cape Town when the official programme of the Association's visits was drawn up; but an unofficial visit to Tokai has been since arranged for Friday afternoon, and I shall be very happy to see there, on that day, all those who take an interest in Forestry. If they will kindly give me their names now, I will make the necessary arrangements for free conveyance by rail and cart to Tokai.

The short time remaining now at our disposal will be fully occupied with the examination of the South African wood specimens on the table.

### 31.—DRY CRUSHING OF ORE PREPARATORY TO THE EXTRACTION OF GOLD.

BY FRANKLIN WHITE.

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The extraction of gold from the rock or from the other minerals in which it is contained may at first sight seem to be a matter of commercial rather than scientific nature. A judicious application of scientific knowledge is, however, generally found to be of great assistance to industrial enterprises.

The Gold and Diamond industries are of great importance to South Africa as a whole, as it is, comparatively speaking, a young country as regards its advance in agriculture and in manufacture of its raw materials; the application of science as affecting gold extraction especially as regards South Africa may, therefore, be reasonably included in the discussion of this Society.

It is impossible to say when or in what manner man first collected and made use of gold. Recent research in Egypt has shewn the existence there of very ancient circular crushing mills very similar to the South American and Mexican "Arrastra" (a word indicating "dragging," from the verb "Arrastrar," to drag, referring to the dragging of mullers or stones over the ore to be crushed), or to the pug mill of the modern builder.

It is claimed that both in papyri and in sculptures, in the ruins of Beni Hassan and Thebes, the system of gold extraction then in vogue is shewn, the general features being the breaking up and pounding of the quartz containing gold until the fragments were made small enough to set free the precious metal, which was then washed out on sloping tables.

The modern stamp mill, which is nothing but a collection of pestles and mortars moved by mechanical means, is a perfected survival of this system. Quicksilver has, however, been made use of as a means of collecting the gold more completely and expeditiously.

The modern "blanket strakes" is nothing more than a cheap, though efficient, substitute for the sheep skin, amid the hairs of which the gold was formerly collected, and the Grecian fable of Jason and the Golden Fleece is probably a poetical reference to a successful raid on a community of alluvial gold washers.

Certain negroes are reported to collect gold by pouring water and sand containing gold on to the woolly heads of their fellows, and then picking out the precious metal.

Man would probably first find gold in alluvial deposits, its presence there resulting from the breaking up and wearing away of gold-bearing rocks by atmospheric disintegration, earthquakes, avalanches, and subsequent pounding in the mountain torrents.

He would then discover gold in the parent rock, and pound it free himself.

As his knowledge expanded, fire would be used as an efficient aid, eventually bringing him to smelt such rocks or minerals as were suitable.

Although these methods in process of time were vastly improved, no notable advance in a new direction was made until Messrs. MacArthur and Forrests made a commercially successful application of the already known possibility of dissolving gold by means of cyanide solutions, and the subsequent collection of the precious metal by using zinc to effect its precipitation.

At first sight this system appears to be simplicity itself. All that is required is (in theory) to break up the rock containing the gold into sufficiently small particles, put the whole into a bath of cyanide solutions, and then collect the gold as before explained.

Metallurgists have always recognised that the recovery of gold by stamps only was limited to say 65% of the actual contents of the ore, and that there was always a more or less considerable proportion lost which remained in the sands and muddy waters produced by their stamp mills.

They eagerly availed themselves of the new method for collecting what was before an apparently unavoidable loss.

The following figures will give an idea of the advantage obtained by this successful application of a scientific fact:—

Gold Output on the Rand in first eight months of 1899:—

Ore milled ... ..	6,067,317 tons.
Gold produced (fine) ... ..	2,976,766 ounces.
Value ... ..	£12,468,617

This gold was obtained:—

	Ounces.	
From Mills ... ..	1,945,236	equals 65.35%
From Concentrates, etc.	74,294	" 2.50%
By Cyanide ... ..	957,236	" 32.15%
	<hr/> 2,976,766	<hr/> " 100.00%

#### VALUE.

Mill Gold ... ..	£8,161,185
Concentrates ... ..	304,398
Cyanide ... ..	<hr/> 4,003,034

Total value ... .. £12,468,617

It can be correctly said that the additional amount of gold won by the use of cyanide converted gold mining on the Rand from a probably insignificant average profit-giving industry into a very remunerative undertaking.

This new and important process has, however, not been accorded its proper place. Instead of being considered as the final and principal operation up to which the others should lead, it has been tacked on as an auxiliary to stamp mills and amalgamation

processes. The reverse should be the case. The mechanical preparation of the ore should be directed to providing a product especially suited to the Cyanide treatment.

It was soon found that the crushed material generally produced by stamps was not well suited to cyanide treatment.

It contains too large a percentage of extremely fine material which fills up the interstices between the larger grains, not only impeding the filtration and efficient draining off of the cyanide solutions from the mass of sands, but also checking the free entrance of air which supplies the greater part of the oxygen required for the efficient dissolving of the gold.

The following table will give an idea of the effect produced by crushing by different systems.

The percentages given indicate the amount of crushed ore or sand which passed through sieves of certain number of meshes per square inch, but remained on the next smaller size.

Mesher per square inch ... ..	400	900	1600	3600	8100
	$\frac{\%}{2}$	$\frac{\%}{2}$	$\frac{\%}{2}$	$\frac{\%}{2}$	$\frac{\%}{2}$
Wet Stamps, 700 Mesh ... ..	—	11.15	28.53	9.21	51.11
Dry Stamps, 400 Mesh ... ..	—	20.30	9.80	21.80	49.10
Rolls, 400 Mesh ... ..	29.00	35.00	—	14.00	22.00
Ball Mill, 500 Mesh ... ..	—	20.07	24.38	13.88	41.67

Rand experience shews that about 25% of the Mill product should be classed as "Slimes," *i.e.*, a material which does not afford free passage to solutions. It is clear, therefore, that wet crushing stamps make a far too large proportion of a finer product than is necessary for efficient extraction of the gold, the excess of which must be removed and treated separately.

Dry crushing by stamps gives even worse results: see the example given where the crushing was stopped at 400 mesh instead of 700.

Ball Mills follow closely on stamps. Rolls, however, give a product, the whole of which theoretically should offer no difficulty to percolation, and this has been found to be the case in practice.

When the ore has been crushed sufficiently fine to allow the cyanide solution to attack the gold and extract a sufficient percentage, any finer crushing is not only a needless waste of power and wear of materials, but is also actually detrimental to efficient treatment.

A distinction must be made between an economically satisfactory extraction and a very high extraction, as the latter may be obtained at a greater cost than the additional gold is worth.

It has been shewn that a very large amount of gold is won from the Mines on the Rand, but it must be remembered that the ore mined, milled, and treated to produce this quantity reached the enormous total of over six million tons, the gold won from the ton (2,000 lbs.) being on the average but 9.81 dwts. (say, 235½ grains) worth, say, thirty-nine shillings and threepence (39s. 3d.).

For this comparatively small value to provide for cost of working, and give profit as well, it will be readily conceded that great care

and economy must be observed in every department and full advantage taken of every assistance that mechanical and chemical science can afford.

A saving of one shilling per ton means an addition of £450,000 to the annual profit from the Mines on the Rand.

Out of the 9.81 dwts. won from each ton of ore, cyanide claims credit for at least 3.17 dwts., and it is very probable that the whole could have been obtained by the latter process.

It is surely worth consideration whether the system of mechanical preparation of the ore which for centuries has only enabled the miner to extract as a rule less than two-thirds of the gold from his ore should not be modified or even changed in order to suit the important additional means with which science has furnished him in the last 13 years, a system which has increased the quantity of gold won by nearly one-half.

It is evident that the ideal crushing machinery or system will be one which can be adjusted so as to reduce the bulk of ore to such a size as will enable an economically efficient extraction to be obtained, the percentage of particles below this size being as low as possible in order to avoid loss of power and the production of the objectionable material known on the Rand as "Slimes."

It is hardly necessary to say that the finer the ore is crushed the greater will be the expense.

When treating comparatively low grade ores such as those of the Rand, or, say, containing  $\frac{1}{2}$  ounce per ton (worth, say, 40s.), great care must be exercised to avoid that the extra cost incurred in crushing and extracting an additional five per cent. (worth, say, 2s.) does not exceed, say, 1s. 6d. (one shilling and sixpence), otherwise the operation would be unprofitable.

On the other hand, ores such as are often mined in Kalgoorlie containing 2 ounces of gold per ton could well afford an increased cost of several shillings, as 5 per cent. of that value would equal 8s.

This Paper deals principally with ores of the lower grades, in dealing with which strict economy is necessary.

A visit to a modern stamp battery in work is necessary in order to realise the enormous effect produced by a number of heavy masses of iron exceeding half a ton in weight being raised six to nine inches at least 90 times every minute and falling on to solid foundations or anvils.

There is no possibility of arresting the action of one of these pestles when in motion, and the ore beneath them stands as much chance of being crushed too fine as of being reduced to the required size.

To crush one pound of Rand ore an effort equivalent to from 7,000 to 8,000 foot pounds is demanded from the engines, not including loss of power from friction, &c.

The impossibility of checking the crushing action of a stamp battery is the cause of the formation of the large percentage of slimes by that method.

Water is used in stamp milling in order to carry the ore from under the stamps. The resulting mixture of slimes and water becomes of higher specific gravity and is more capable of carrying off fine particles of gold than pure water could do. Subsequent careful settling is necessary in order to collect these particles, and the result of the creation of these undesirable slimes was the evolution of the "slimes treatment," the weak point in the Cyanide process.

The addition of lime to the water used in Mills has reduced the difficulty in settling, and also lowered the value of the slimes, but unfortunately without leaving the slimes sufficiently poor to throw away.

Dry crushing, chiefly by means of rolls, offers a solution of the problem. The ore can be crushed without water, and the degree of crushing can be controlled to a far greater extent than in stamp mills.

This system has an additional favourable feature, and that is that in the case of many ores the whole of the gold could be extracted by cyanide in one operation and the cost of the amalgamation process avoided.

To obtain successful results the ore should be broken down in stages.

The material as it comes from the Mine often being in large pieces should be first roughly broken in a powerful rock-breaker and then passed on to a smaller sized machine which would still reduce it to a smaller size. From these machines it should be fed to the rolls, each set being adjusted to take the ore from the preceding machine and again reduce it in size. By this means each machine will be kept working on pieces of a size which suits its design and adjustment, and the power available will be economically used.

The advantages obtained in crushing the ore dry preparatory to cyaniding may be put down as:--

1. Economy in expenditure of power partly due to the crushing of the ore being carried only to the extent necessary to give a good extraction, and partly to the use of more economical crushers than the gravitation stamps.
2. The outlay in machinery will be less in proportion to the saving in power.
3. Economy in water required, as a ton of dry crushed ore can be successfully treated at the expenditure of less than one quarter of a ton of water, whereas stamp batteries require a very large amount, frequently passing five tons.
4. The possibility of winning the gold in one operation, namely by exposing the whole of the ore to one cyanide treatment instead of having three operations, i.e. amalgamation, cyanide treatment of coarse sands and collection and treatment of the slimes.

The objections raised against Dry crushing can be summed up as follows:

1. Increased wear of crushing surfaces.
2. Injurious effects on workmen, machinery, &c., from the dust produced.
3. Difficulty of crushing and sifting the ore if it is damp.

4. Expenses incurred in crushing fine enough to separate the gold from the rock.

5. Impossibility of dissolving coarse gold by cyanide.

For some reason or other Engineers in South Africa have looked upon any departure from the venerable process of wet milling with little favour.

In other parts of the World very large quantities of gold are being produced from dry crushed ore. Alfred James in his work on Cyanide Practice refers to the "Mammoth installations of the Metallic Extraction Company"; "The Economic Gold Extraction Company"; the "De la Mar Mines" at Mercur, all in America, the latter plant being able to crush 750 tons of hard ore per day to 1/8th inch mesh. At the Waihi Mines in New Zealand hard ore is crushed dry in the ordinary stamp battery, an application of an unsuitable machine to a good system, but the results are nevertheless satisfactory.

In the famous Mount Morgan Mine in Queensland (p. Argall on Sampling and Dry crushing in Colorado) in one year 175,000 tons were crushed by rolls and Krupp Ball Mills to a 1/43rd inch, and in Borneo extremely coarse dry crushing has given very good results.

Some of the American dry crushing mills deal successfully with the troublesome telluride ores.

It should be possible to deal with some of the South African ores by dry crushing, although of course some are not suitable, but the most important class, namely the Rand Conglomerates, do not offer any special difficulty, as on the one hand they contain practically an inappreciable amount of coarse gold and on the other they do not require to be crushed to the extreme fineness of, say the Kalgoorlie ores, which are commonly reduced to pass a sieve of 40,000 holes per square inch.

The "Marriner" and "Diehl" processes which give such successful results in Kalgoorlie ore require extremely fine grinding as an essential.

The "Objections" should be dealt with first, for if these can be overcome the "Advantages" are too obvious to require much to be said in their favour.

1. *Wear of crushing surface.* This is given by Argall as 0.108 lbs. per ton of the rather soft and friable Mount Morgan ore. It is crushed to pass sieves of 1,600 holes per square inch.

At the Luipards Vlei Mine, Witwatersrand, the wear on a mixture of free milling and pyritic ore was found to be 0.805 lbs. per ton crushed to 200 meshes per square inch. The wear of shoes and dies on a typical Rand mill (Wet stamps) crushing to say 600 meshes per square inch is returned as 0.75 lbs. per ton of ore crushed. There is therefore not much difference between the two processes as regards waste of metal.

2. *Dust.* In a well-constructed Roller Mill the escaping dust is practically inappreciable, especially if the ore is somewhat damp.

3. *Damp Ore.* The cost of drying is not alarming. Argall gives it at 5 cents (2½d.) per ton to bring moisture down from 6% to 1%. At the Wanderer Mine, Southern Rhodesia, damp ore containing

11% to 15% moisture is reduced without difficulty to 2% by means of Pape Henneberg driers. Ore with 4% moisture is workable without drying. The driers are only used in the wet season.

4. *Expense incurred in fine crushing.* This is frequently overdone. Rand practice is gradually altering and coarser crushing is gaining ground. At the Luipards Vlei Mill, pyritic ore crushed to 700 mesh per square inch was reduced in value to  $1\frac{1}{2}$  dwts., indicating an extraction practically as good as the average obtained in Wet Milling plants.

5. *Difficulty of dealing with coarser gold.* This is of course an important and positive objection, when it does exist, but in the majority of cases the gold is fine enough to be freely dissolved. Gold which passes through a sieve with 200 or 300 meshes to the inch can be dissolved without much difficulty, and coarser particles should not escape if the sieves are working properly but be returned to the crushers for further reduction.

#### ADVANTAGES.

1. *Saving of power.* This brings with it less capital outlay in plant as well as in working cost. The economy will more than counter-balance any possible excess in cost of renewals.

At the Wanderer Mine, friable ore of very low grade is economically crushed and cyanided when crushed to pass sieves with clear apertures of  $\frac{3}{16}$ ths inch square, or 16 to the square inch. The final residues do not exceed one dwt. in value per ton and the quantity treated at present is 2,000 tons per week.

2. *Simplicity of operations for extracting gold.* Plate and battery amalgamation are not required. The smaller percentage of slimes produced can be mixed with the sands, and the whole treated by cyanide in one operation instead of two. The material produced is more suited to the action of cyanide solutions and consumption of this chemical is lessened.

3. The amount of water required is very little; the cost of pumping is reduced to a minimum, and the large outlay in dams and pumping plant inseparable from a stamp battery is reduced to a minimum. The balance is decidedly against wet crushing.

A dry crushing plant is not recommended, however, for installations dealing with less than 100 tons per day.

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### 32.—SEWAGE DISPOSAL IN CAPE COLONY.

By J. EDWARD FITT, A.M.I.C.E.

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In dealing with the question of Sewage Disposal in Cape Colony very little can be said about what has been done up to the present in this direction, as with the exception of Cape Town, Sea Point, and Simon's Town, which have water carriage systems of sewerage with sea outfalls, all the Towns and Villages of this country adopt the pail system, and the night soil from these receptacles is invariably disposed of by burying in the ground, the manner of carrying out the work varying only according to the nature of the ground available for the purpose or to the fancy of the contractor who undertakes the sanitary removals.

A feeble attempt is made by some Municipalities to cart away the urine, slop-water, and other liquid sewage, and dispose of this by emptying it upon the land set apart for the reception of the night soil; but as a rule this portion of the sewage is allowed to soak away, if it can, into the ground, or to find its way into the nearest water-course.

The only works for sewage disposal that have been carried out in this country are some small installations of the Scott-Moncrieff plants which have been erected in several places to deal with the sewage from private houses and institutions, some of which have been very successful in their action, and the works which have recently been established at the Native Location, Maitland, for the purpose of dealing with the sewage of a population of about 7,000. These works, which will be referred to later on, comprise a septic tank, single contact bacteria beds, and final treatment of the effluent by intermittent filtration through land.

From this summary of the present sanitary conditions in the Colony it will be seen that the question of Sewage Disposal here is all for the future. We are fortunate in this respect that before any important works of this description have been carried out, the problem which for so many years defied solution has, after much expenditure and many failures, been practically solved by modern research which has shown that, under favourable conditions, sewage is capable of bringing about its self-purification by means of bacteria which are indigenous to all sewage, and that these favourable conditions are not difficult of attainment, so that this country will be saved the costly failures that have resulted from all attempts to deal with sewage by chemical treatment which so many English and European Towns have experienced when dealing with the question of the disposal of their sewage.

The Bacterical treatment of Sewage is effected by:—

- (a) Septic Tanks.
- (b) Contact Beds.
- (c) Intermittent continuous filtration.

The Septic tank is one through which the sewage is allowed to flow at a slow rate so that the suspended matter in the sewage sinks to the bottom of the tank where a certain percentage of it is, in time, either liquefied or changed into gaseous products, thereby reducing the amount of sludge which has ultimately to be dealt with, while at the same time a bacterial action or fermentation is set up in the tank and we have a self-purifying process or "working" of the sewage. The result is a liquid from which has been removed a large percentage of the solid matter in suspension and a smaller percentage of solids in solution. Just how much of these solids are removed depends on such conditions as the strength and condition of the sewage, the general temperature and the rate of flow through the tank, under favourable conditions the amount of sludge decomposed appears to be from 26 to 30 per cent. of the total suspended matter arrested in the tank.

During the past five or six years the Septic tank has been installed in a great many places and while it cannot be considered a complete solution of the sewage purification problem it has come to be looked upon as an essential first stage in the bacterial treatment of sewage, and in one form or another now takes its place in all sewage disposal works.

"Contact Beds" are filters of porous material in which the sewage is allowed to rest for a certain length of time in contact with the nitrifying bacteria which form in the filter and which by their life process effect a chemical change in the sewage by which it is purified. The essential principle of the beds is that a certain amount of time should be given between each filling of the beds to allow them to thoroughly aerate in order to supply the organisms with the atmospheric oxygen which enables them to perform their work.

Beds on this principle have been extensively used in various parts of the world during the past few years with success. The percentage of purification effected by them depends largely upon the regularity in which the periods of filling, standing full, emptying and standing empty or aerating is maintained. These contact beds were originally used for treating crude sewage but are now used in conjunction with septic tanks and it is generally conceded that sewage after having undergone preliminary treatment by the septic tank process can be purified by contact beds so as not to undergo secondary putrefaction at the rate of 500,000 to 1,000,000 gallons per acre per diem.

The system that for want of a better title is known as the "Intermittent continuous filtration" method to distinguish it from continuous filtration effects the purification of sewage by the same process as the Contact Beds, the difference in the action of this method being that instead of allowing the sewage to remain in the filter in contact with the nitrifying bacteria for a length of time it is passed through the filter in a thin continuous stream, the supply of atmospheric oxygen that is necessary to enable the bacteria to perform their function being attained by special construction of the filter and by the means

taken to apply the sewage intermittently in a thin stream or in the form of drops or spray.

The filters on this system which are being tried at the present time are the "Scott Moncrieff," the "Ducat," the "Whittaker-Bryant," the "Corbett" and the "Stoddard" filters.

Without going to the length of describing the methods upon which these different filters are constructed I may state generally that these filters are used in conjunction with the septic tank and are capable of dealing with a greater amount of sewage than the contact beds. The "Ducat" filter is said to deal with sewage at the rate of 1,000,000 gallons per acre per diem; one of the largest plants on the intermittent continuous system—a "Whittaker-Bryant" plant erected at Church near Accrington—is dealing with sewage at the rate of 2,000,000 gallons per acre per diem and the purification is said to be good, while a small "Stoddard" filter erected near Bristol has been running successfully at the rate of 5,000,000 gallons per acre per diem.

The construction of these filters, with the exception of the last named, is more costly than that of contact beds, and owing to the special means that have to be taken to ensure complete aeration the cost of maintenance is considerable.

A brief description of the Sewage Purification works on the Contact system which have been constructed at the Native Location, Maitland, may be of some interest.

The sewage is brought from the various parts of the location to the sewage works in iron trolleys running on an 18 inch gauge tramway, where it is emptied into a screening chamber and from thence it passes over a weir into a septic tank. This is a covered tank with a capacity of 6,000 gallons, which is estimated to be the quantity of sewage that will be treated daily when the various sanitary conveniences in contemplation have been constructed. The septic tank is fitted with partitions or scum boards at a distance of one foot from each end, which extend from above water line to within two feet six inches of the bottom, an arrangement which causes the liquid passing from the tank to be drawn from the middle portion, leaving undisturbed the sediment which is deposited at the bottom and the thick crust or scum which forms at the top; a weir is formed at the outlet similar to the one at the entrance extending the full width of the tank and over this the effluent passes in a thin film to a collecting tank designed to contain 1,000 gallons; in this tank there are fixed two syphons set to discharge the whole of the contents of the tank when the liquid reaches a certain level; these two syphons work automatically and discharge alternately on to two bacteria beds which are constructed immediately below the tank.

The bacteria beds are designed to contain 1,000 gallons in addition to the filtering material so that each time one of the syphons discharges the contents of the collecting tank one of the bacteria beds is filled while the other bed is being aerated preparatory to coming into work at the next filling of the collecting tank.

The bacteria beds are fitted with automatic timed discharge syphons operated by the liquid in the beds passing through a small regulating cock which can be set so as to start the syphon and discharge the contents of the bed after it has been in the bed, and consequently in contact with the bacteria, any desired length of time.

When these beds are working up to their full capacity each bed will be filled three times during the 12 hours of day and will stand empty to aerate during the 12 hours of night.

The filtrate from the bacteria beds passes into an effluent channel which discharges into an irrigation furrow, from whence it is led over the land in furrows or on to beds according to the requirements of the crops to be irrigated.

Each of the Bacteria Beds is 20 feet long by 8 feet wide and averages 3 feet in depth and when working to their full capacity will deal with sewage at the rate of 822,800 gallons per acre per diem.

The cost of the construction of the works was £400.

The information and data which we have regarding the bacterial system of sewage purification is derived from works which have been constructed in countries which have a humid climate, where on account of the dense population it is desirable that the area set apart for sewage disposal should be as small as is compatible with the purpose and where the excessive rainfall makes it necessary that the superfluous water should be got rid of as soon as possible. In this country those conditions are reversed; here we have a dry climate and at present a scanty population, and under these conditions the waste water from sewage works instead of being looked upon as a necessary evil, to be got rid of as soon as possible, would be stored for irrigation purposes and thus form a valuable asset. The area of land which would be utilized for the final treatment of the purified effluent instead of being as small as possible would be as large as the volume of water would irrigate, and when we consider that the application of water to land increases its value from £1 to £20 per acre it seems reasonable to assume that the cost of carrying out Sewage Disposal Works in this country will be largely met by the increased value of the land utilized and by the sale of the waste water for irrigation purposes.

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### 33.—THE IRRIGATION QUESTION IN SOUTH AFRICA

BY W. WESTHOFEN, M.I.C.E.

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The climatic conditions prevailing in South Africa—the uncertainty and insufficiency as well as the inequality in distribution of the annual rainfall, make it absolutely necessary that irrigation should be resorted to if the country is ever to be made a self-supporting one so far as the production of foodstuffs is concerned.

Thousands of square miles of the most fertile land are lying waste—more particularly in the Cape Colony, owing to the want of this most essential adjunct to agriculture and husbandry in a semi-arid climate.

Irrigation has been practised in South Africa from time immemorial no doubt, yet it may be said with much truth, that the manner in which the aboriginal has led water on to his little patch differs but little from that in which irrigation is practised at the present.

Broadly speaking, when it has pleased Providence to provide the element, man has, in a leisurely way, seen fit to utilize it, and when it has pleased Providence to withhold it man has tamely submitted to do without it.

Within the last 30 or 40 years some progress has certainly been made, mainly by individuals who tried to benefit by the experience gained in other countries and to utilize the advantages which scientific research and engineering skill has placed at their disposal. But these efforts were spasmodic and never on a scale which could result in profit to the whole community rather than to the individual.

It is the object of this paper to examine to some extent into the causes which underlie the want of progress in a matter so deeply concerning the welfare of this country and its inhabitants.

First and foremost must be held the fact that all public works are to a great extent looked upon as counters in the political game. However enlightened a Government may be and however anxious to further a good cause, it is controlled by Parliament and it has not the power to pass measures which have not the approval of a majority in the Legislature.

No one who has followed the debates on Irrigation in the House of Assembly could fail to be struck with the extremely narrow and—if the term be permissible—parochial views which are held by the majority of country Members and which find expression in their speeches. It is evident that they are ignorant of what has been done in other countries and cannot realise that only by co-operation and by working unitedly for the benefit of the whole Colony can any

material success be achieved. On the contrary they seem each and all interested only in the fortunes of the particular Districts which they represent and the idea of one District receiving a large grant of money in which others are not to share equally is utterly abhorrent to them.

Thus, whenever a large Government Irrigation scheme is proposed some Member is sure to rise and argue that it would be far better to allow 500 farmers to have an irrigation dam each at the public expense than that the whole of the sum total should be spent upon one comprehensive scheme in a single District. And that Member invariably secures considerable support in his contention.

Next in importance to the subject just mentioned is the fact of the non-existence of efficient and comprehensive laws dealing with the ownership of water and its apportionment. Although the subject has been brought to its notice year after year for nearly half a century, the Legislature of the Colony has never yet made a serious effort to establish a code of laws which would once for all settle the vexed question of water-rights. It has acted rather on the assumption that the existing laws, such as they are, may be looked upon as sufficient, and has contented itself in facilitating their application in certain directions.

Various Bills dealing with irrigation were submitted to the Legislature between 1861 and 1875, but these were either rejected by the Council or by the Assembly, or else withdrawn by their proposers.

The first Act which passed the Legislature and became law in the Colony was Act 24 of 1876, called the "Right of passage for Water Act," dealing with the right of conveying water for irrigation purposes across other persons' lands and with matters connected therewith. This Act was, however, repealed by Act 26 of 1882.

In the year following another Act was passed, Act 8 of 1877, constituting Irrigation Districts and Irrigation Boards, defining their powers and duties, the raising of loans and fixing of rates of interest and repayment, providing for irrigation schemes promoted by private individuals, granting them powers to raise loans in Districts where Irrigation Boards had not been constituted and laying down regulations for the settlement of disputes by Arbitration.

Act 28 of 1879 provides for Municipalities exercising under certain conditions the same powers as Irrigation Boards with regard to the raising of loans and the imposition of general rates for purposes of irrigation or domestic water supplies.

Act 7 of 1880 was passed in amendment of Act 8 of 1877, enabling Government to advance instalments of one-fifth of the total amount of a loan granted under previous Acts in order to assist in the construction of Works and to cover preliminary expenditure.

By Act 26 of 1882, as already stated above, Act 24 of 1876 was repealed. It provides more in detail the means of passing water over the lands of other proprietors, compensation by arbitration and limitation of servitude.

Act 10 of 1893 introduces a modified scale of repayment of loans granted under preceding Acts.

Act 33 of 1896 provides for the construction of certain irrigation works by Government, namely Kenhardt, Steynsburg and Calitzdorp.

Act 24 of 1897 makes further provision for advances to Irrigation Boards, Municipalities or private persons, and for payment of interest and repayment of capital advanced.

Act 40 of 1899, commonly called the Water Act, 1899, deals with the establishment and the constitution of Water Districts and Water Courts, solely for the settlement of disputes with regard to Water rights. These Courts have very full powers in reference to rights of abutment in constructing weirs across watercourses, in deciding what materials should be used in the construction of such weirs or dams, in apportioning or distributing the available water among the various proprietors interested and in fixing the liabilities of all such proprietors with regard to expenditure incurred in the construction and maintenance of Works, and finally, in dealing with questions of compensation. The Act further empowers the Governor to disregard section 66 of Act 8 of 1877 which insists upon all loans being secured by first mortgage on the properties interested and to accept a second mortgage provided the value of the security offered be sufficient to cover both first and second mortgage.

The last Act passed, No. 19 of 1902, provides for the construction of the Thebus Irrigation Works by Government.

It will be noted that in none of the above Acts has an attempt been made to touch the thorny subjects of water-rights or to define such in any way. Consequently in all cases where disputes about water-rights cannot be settled amicably or by arbitration, recourse must be had to the Supreme Courts of the Colony—a fact which has a most deterrent effect upon investment of capital in Irrigation enterprise.

Although these Acts provide, to all appearance, everything in the way of assistance to enterprise, yet as a matter of fact they have not proved so successful in operation as had been expected. This is proved by the fact that but few persons or public Bodies have availed themselves of the facilities offered, and the reasons are not far to seek. Some of the conditions attached to the granting of loans are extremely onerous in many cases and in some absolutely prohibitive.

Months are often spent in the examination of titles in connection with the mortgages, and in the end the loan is refused for some reason or other.

Again, the terms of various Acts with regard to loans are contradictory or insufficiently clear and several of the Acts require amendment. For instance it is laid down in Act 7 of 1880 that Government may advance one-fifth of the total loan granted. Such an advance is undoubtedly of great assistance to men who do not command a large capital, but the Act leaves it uncertain whether further advances can be made when the amount of the first advance

has been duly and satisfactorily expended upon the Works, while another Act lays it down that advances can only be made to the extent of two-thirds of the value of work actually carried out and certified to by a Government Engineer. Thus assuming that a loan of £5,000 had been granted, an instalment of £1,000 would be advanced on starting the works, but the applicant must spend an additional £2,000 of his own money (or £3,000 altogether) before a second instalment of £1,000 could be advanced to him, and he would have to expend a total of £4,500 before he could receive a third instalment of £1,000. If the applicant has not sufficient capital of his own it is obvious that he will have to borrow elsewhere, probably at a high rate of interest, and it will thus be seen that the assistance offered by Government is less in reality than would appear from a superficial examination.

The Acts should therefore be amended in such a manner that it would be possible to advance a second instalment of one-fifth of the total so soon as the first instalment had been properly expended upon the work.

It must be considered that an enterprising farmer who raises a loan or mortgage runs a very considerable risk of losing his property, should for instance an abnormal flood occur, which might sweep away the whole of the Works while under construction, and to such men every assistance and encouragement should be given in the furtherance of their objects.

Other reasons why Irrigation enterprise has not prospered may shortly be stated:—

Want of capital.

Want of experience.

Ignorance of the best methods of storing water or of applying it to the best advantage when it is available.

Absence of public spirit and disregard of the value and the advantages of co-operation among the persons most interested.

It would be absurd to question the wisdom of the policy of constructing roads and railways in order to open up the interior of a country and so allow its produce to be distributed in the country itself, or else to be forwarded to the ports whence it can be shipped to other countries. But it is equally the duty of the Government which provides the means of transport to render assistance to the producer in the only way in which he should be assisted in the semi-arid country, namely, by supplying him with the water he is in need of. For a railway once it is constructed may carry a thousand tons a week, but it can be made to carry ten times that quantity at comparatively little extra expense. In the former case it may be worked at a loss, in the latter at a profit. It stands to reason, therefore, that if the producer is enabled to double or treble the amount of his produce the railway and the whole country must benefit by it.

Hitherto the assistance given to the producer has mainly been in the direction of protective duties, which course, while benefiting

him to a slight extent, has had a most disastrous effect in abnormally raising the cost of living. And what is worse, these protective duties have in many instances induced the less industrious and less progressive class of farmer to cultivate less of their lands because the increased price of the produce has yielded them the income which satisfied their wants.

The serious falling-off in the agricultural produce of the Colony may not be altogether due to this cause, but from the many instances reported of less land being under cultivation it is not unfair to come to the conclusion that it has a great deal to do with it.

It may, therefore, justly be urged that the construction of roads and railways should go hand in hand with irrigation works which will help to make the railways pay, and which may ultimately not only provide food-stuffs for the people of this Colony, and so make it self-supporting, but may even open up a trade with other countries in articles which are now imported in large quantities.

And, further, the subject of irrigation should be treated in a broad and generous spirit, and so long as there is a reasonable prospect of the people generally benefiting by this policy, the question, whether a scheme is likely to pay interest in one or two years on capital expended should never be raised nor should it influence a decision.

The subject of irrigation may be broadly divided into two main sections :—

1. The collection and preservation or storage of water.
2. The utilization of the water to the best advantage after it has been stored.

With regard to the first, it is not to the credit of the Legislature that so little has yet been done in that direction. One of the most important features in connection therewith is the knowledge of the amount of water available at a given point, and to obtain this the very first requirement is a complete hydrographic survey of the Colony.

It is true that a commencement was made as early as 1860, when Government established the Meteorological Commission—the labours of which have resulted in furnishing a number of useful data. The Commission has placed a large number of rain gauges in different parts of the Colony, and has arranged for readings to be taken and recorded. These results are published year by year in a report to Parliament.

The funds placed at the disposal of the Commission are quite inadequate, however, for the purpose, and the rain gauges far too few in number to furnish anything but very general data. With one rain gauge to perhaps one hundred or several hundred square miles sufficient information of a reliable nature cannot be obtained, more particularly when it is considered that there may be plains adjoining mountain ranges rising to 3,000 and 4,000 feet, with the rain gauge placed—not at a point where a fair average fall might be registered, but in a place where the unpaid observer can conveniently get to it.

The data obtained from rain gauges, however, are not in themselves conclusive, inasmuch as in all cases the whole of the rainfall could not be collected or stored owing to the absorption by the soil and evaporation by sun and wind. Hence it is necessary, in order to arrive at a correct idea of the amount of water available, to measure, in conjunction with the rainfall, the amount of flow-off in river channels.

This is the object of the proposed hydrographic survey, the importance of and necessity for which has been impressed upon successive Governments, but so far without result.

In this Colony, where we do not derive any water from the eternal snows which are denied to South Africa, we are dependent entirely upon rainfall and its conservation, and to our rivers we must look for our supplies—yet of the capacities of our rivers we are as yet absolutely ignorant.

The hydrographic survey is necessary to establish:—

1. The amount of rainfall over a given area, which is called a watershed, and which embraces the sources and tributaries of a great river.
2. The periods of the year during which such rainfall occurs in the various sub-divisions of a watershed.
3. The amount of flow-off at various points along the course of the river, that is, the difference between the total quantity of rain-water which falls and that which has evaporated, or has been absorbed by the soil before the point is reached at which measurements are being taken.

As a ground work or basis upon which such observations will be made, the Colony has been divided into ten distinct hydrographic areas or districts, each of which comprises the whole of one or more large rivers, and each such district may be sub-divided into smaller districts, which may embrace one or more of the tributaries.

The first work of the survey would consist of laying down definite boundaries for each district or sub-district, and to ascertain the exact superficial area of each. Rainfall statistics would be obtained at various points in order to establish a fair average figure for such rainfall, and at suitable points measuring weirs would be placed to ascertain the amount of flow-off. Similar weirs placed at or near the confluence of several tributaries would establish a check upon the detailed readings, and would allow of arriving at a fair estimate of the losses due to soakage and evaporation in the larger channels.

Data collected in this manner would be of the greatest value and utility in estimating within a comparatively short period of time the potentialities of any irrigation scheme submitted to Government, while under present conditions much of the information required has to be guessed at or based upon entirely insufficient information. Nor are such data of use in the case of irrigation alone.

In the designing of bridges, for instance, the principal item of knowledge required is the maximum flood level recorded at the site fixed upon. At present it is an established custom, when

direct evidence is not obtainable, to consult the oldest inhabitant, but the information furnished by those worthies is frequently very misleading and incorrect in recorded instances by 8 to 10 feet in the height reached by a flood. The designer naturally does not wish to place his structure higher than necessary for safety—to avoid unnecessary expenditure in piers, abutments, embankments, and approach roads—yet, on the other hand, placing it a foot or two too low may spell disaster, and much greater expenditure in the end.

Equally important is the knowledge of river flows in the case of water supplies for villages or towns or for industrial purposes.

During the sittings of the Peninsula Commission the writer was asked to furnish information with regard to the approximate cost of surveys of the river sources of some of the principal streams within 50 or 60 miles of Cape Town. In not a single case were any data available shewing the extent of the watersheds, the average rainfall, or the amount of flow-off, all of which would have been found in the records of a proper hydrographic survey.

Such a survey would also disclose the localities where permanent weirs might be constructed to retain some of the water, which now after heavy rains disappears into the sea in the course of a few hours, thus robbing the agricultural lands of an inestimable benefit.

Many of the Colonial rivers, such as the Orange, the Great Fish, the Oliphants, the Gamka, the Gouritz, and many others, carry with their flood waters into the sea immense quantities of soil and organic substances extremely valuable as fertilising agents. A series of low weirs with sluices in each would hold up the greater bulk of such matters, and when the floods have subsided the sluices could be gradually opened, the water drained off, and the deposits allowed to solidify, after which they could be carted away and deposited upon the poorer lands and ploughed in. Or in places where the configuration of the ground is suitable the silt laden flood waters could be led upon such lands direct.

Another useful feature of the hydrographic survey would be the gradual collection of data regarding what has been done or is doing at the present time in the various divisions of the Colony in the way of irrigation. Of such very little is to be found in official records, and this mostly in connection with schemes carried out within the last decade. It is well known, for instance, that irrigation is practised on a fairly large scale in the Oudtshoorn District, but what this actually amounts to, what crops are raised, and in what quantities, what area of land is actually under irrigation, the amount of water consumed, the manner of its distribution, the sources from which it is taken, are all matters which may be well known to a few local people, but of which nothing reliable can be obtained from official records.

This paper has so far dealt with rain water stored directly after it has fallen. There is, however, another supply available, namely, the water which has been lost to ordinary storage by having percolated into the ground and formed natural storage reservoirs in

crevices or cavities in the pervious strata. Such water can be reached and recovered by means of tunnels, if in the hill side, or else by boreholes or wells. A paper on this subject will be read during the present session, and it is not necessary, therefore, to say here more than that the cost of raising such water to the surface is, owing to the scarcity and high price of fuel in the Colony, at present prohibitive except when dealing with comparatively insignificant quantities.

The same drawback exists in the case of rivers with high banks, where the lands to be irrigated are situated some 30 to 40 feet above the river bed. Several very promising irrigation schemes on the Orange and other Colonial river systems had to be abandoned through this cause, the local conditions being such that only by an abnormally long canal, the maintenance of which would be much too costly, could water be conveyed to such lands by gravitation.

With regard to the second main point, namely, the utilization of the water collected and stored, this falls partly within the scope of the Engineer and partly within that of the Agriculturist and Chemist.

To the Engineer belongs the construction of the head works, the main canal, sluices, aqueducts, flumes, flood gates, overflows, bridges, and so forth.

The main difficulties are met with in the construction of the main canal, passing as it does through soils and materials of all sorts, now through hard rock, next through gravel or through sand, when pitching with stone or puddling with stiff clay may become necessary.

Rivers and swamps have to be dealt with in the most economical manner, and overhanging krantzes negotiated by laying pipes or flumes on brackets fastened to the rock. Careful and accurate levelling is of the utmost importance in order that the water may have a gradual fall towards the end. The hydraulic gradient must be reduced to a minimum in order that a maximum of irrigable land may be commanded, in recent cases the fall being as little as 8 to 9 inches per mile.

Much trouble is caused to weirs and canal banks by moles, crabs, and rats, which burrow for sustenance and moisture under the bottom and through the banks, and cause serious leaks which are difficult to locate and to stop. The tramping of cattle and sheep up and down the banks in search of water also causes frequent damage, and last, though not least, thunderstorms and winter floods frequently destroy in the course of a few hours the work of many months.

Into the question of applying the water when it has been brought to the lands it is not the object of this paper to enter—it is a very large and very important subject for this Colony, and will probably be dealt with on a future occasion.

Under the Acts enumerated above only two public schemes have so far been constituted.

Some 15 years ago an Irrigation Board was established at Warrenton on the Vaal River, and has been in existence since. It is

said to be successful, but no data whatever as to its development or its present condition are available.

About the same time the first Government scheme was started at Douglas, on the Vaal River, not far from its confluence with the Orange. But it was badly conceived, and had to be entirely reconstructed in 1893-95 by the Public Works Department.

There is water in abundance and good land, but the spirit of enterprise and co-operation is wanting.

A large number of erven have been sold, and at good prices, but the people complain that they have no market for their produce, and so restrict their energies to the production of what they require for their own immediate use.

A road is now being constructed from Douglas to Belmont—a station on the railway to Kimberley—and facilities will be given for the disposal of all produce on the Kimberley market.

The most successful scheme so far is undoubtedly that of the Breede River Irrigation at Robertson. It was originally contemplated to start this as a Government scheme, and the route of the canal and the irrigable lands were surveyed, but the amounts asked as compensation by the owners through whose properties the canal was to pass were so large that the scheme had to be abandoned.

Subsequently a few of the more enlightened and energetic proprietors formed themselves into an Irrigation Board, with the sanction of the Government, and raised a loan of £30,000 for the construction of the works. These consist mainly of a weir in the Breede River, about six miles above Robertson, and nearly 21 miles of main canal. The weir itself is 1,200 feet in length, and consists of a concrete wall or core backed by pitched rubble slopes on each side. The concrete core is 15 feet in depth, and is carried down to 8 feet below the river bed. The stone for the backing had to be conveyed for a distance of nearly two miles.

The work was started in February, 1900, and would have been completed about 12 months ago but for the abnormal flood of February, 1902, which did a great deal of damage to some of the minor works. The weir itself, however, has successfully withstood the severe Breede River floods, some of which overflowed it to the extent of 9 feet.

The canal terminates near Ashton, and discharges its surplus waters into the Cogman's Kloof River, but a further extension of about  $3\frac{1}{2}$  miles is contemplated.

The total area to be irrigated by the scheme is about 5,200 acres, and though in an unfinished state lands have been irrigated for many months past at a distance of from 14 to 16 miles from the head works.

It is interesting to note that the compensation paid to land-owners along the line of canal has, under the arrangements made by the Irrigation Board, not amounted to as many hundreds as thousands were asked for when it was looked upon as a Government scheme.

In concluding this paper, it is only fair and just to acknowledge that the present Government, since peace has once more been proclaimed, has—in the person of the Commissioner of Public Works (the Hon. Arthur Douglass)—taken active and energetic steps to place the subject of irrigation in the forefront of public works to be carried out in the immediate future.

During the last Session of Parliament a Bill passed the Legislature authorising the construction of the Thebus Irrigation Works, at an expenditure approximating £150,000.

This work was practically commenced some months ago. Further schemes are contemplated to be submitted to the ensuing Session of Parliament, and all those interested in the question of irrigation may, therefore, look forward with hope and confidence to an era of prosperity and progress in this our Colony of the Cape of Good Hope.

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### 34.—THE ARTESIAN WELLS OF THE CAPE COLONY.

By BERNARD WILLIAM RITSO, M.INST.C.E., F.G.S.

#### TERMS USED.

As a doubt exists in the minds of many whether there is a difference or not between a bore, a boring, or a borehole, and an artesian well, it is better at the outset to make this clear.

From early times holes have been bored into the earth to tap subterranean water confined, in porous strata, under sufficient hydrostatic pressure to rise to the surface, and as wells of this description were first known in Europe in the French Province of Artois, the term "artesian" implied originally a boring from which water flowed at the surface, or was spouted above it, like a fountain. In many cases, however, the pressure was not sufficient to raise the water in the borehole to the surface; still, the same term was applied to all wells from which water could be conveniently pumped. To-day, judging from current European literature, the term "artesian well" is used to designate all vertical shafts of narrow dimensions put down for the especial purpose of obtaining water, in contradistinction to the expression "well," which signifies a vertical shaft of much larger diameter. The American terms "drilled-well" and "dug-well" express the meaning excellently, and are synonymous with the present use of "artesian well" and "well."

#### SURFACE FEATURES.

The geography and superficial features of this Colony, which now includes Bechuanaland and the Transkeian Territories, are too well known to require more than a passing remark. The land rises from the sea towards the interior in a series of terraces, formed by ranges of mountains, which, having comparatively little slope on the landward side, constitute a succession of gigantic steps from the coast to the Great Karroo, a plateau which can be described as a part of the central tableland of South Africa. The position of the coast plateau, of the Southern and Central Karroos lying between the ranges of mountains and the Northern Karroo and Bechuanaland beyond them, as well as the situation of the Eastern slope and the Transkei, are familiar. The relative heights of these plains have been noticed by everyone travelling from Cape Town by rail towards the Orange River, but few people have become acquainted with the geological structure of the country, upon which so much depends with regard to the existence and accessibility of underground supplies of water, so that a brief sketch of it may assist in explaining some of the allusions to geological data in connection with artesian wells in this Colony.

## GEOLOGY.

The systematic study and correlation of the facts recorded in the rocks, which throw light on the general structure of the more westerly part of the African Continent, have been carried on by the Geological Commission during the past seven years, and the collection and interpretation of the phenomena met with have done much in deepening the basis of the foundation of the earth's crust in these regions, and have, on that point, unraveled the mysteries of the far distant past.

The vast range of time which these archives embrace is happily divided into the periods of a change of climate, singular for its stability and unexpected in so remote an era; and this can be conveniently used to separate the groups of sedimentary strata into the older and the younger rocks, especially as the much tilted position of the former contrasts with the nearly horizontal beds of the latter.

There is no beginning to this history, only, far back in the early stages of continental evolution in this hemisphere, a group of rocks of aqueous origin was formed, but where the sediments came from, or how these sea deposits were made, is a subject difficult even to speculate on. Nothing can be seen but the remnant of an ancient land, a relic of the remote past, planed down to a sea level by the denuding forces of countless ages, crumpled by stupendous crustal movements, and through it have intruded the once molten masses from below, which, sunk again deep below the ocean, for millions of years perhaps, have made a foundation on which to build another Continent—one we know more of.

A part of this Continent, which probably extended far to the South, and possibly was connected with India and Australia, is the land of to-day in the Southern portion of this Colony. It has been formed, layer by layer, in ancient seas, of the water-borne debris of Continents no longer known in connection with the present distribution of sea and land. Again, it has risen above the surface in obedience to the mysterious laws of elevation and subsidence, to which land appears subject, and the very alphabet of which is as yet dimly understood. Standing thus, exposed to denudation, active through a hundred thousand centuries, its upper beds have, in places, been cleared away, and even the lowest strata laid bare. In the Cape Peninsula the first layer of Table Mountain sandstone can be seen resting on the tilted strata of the ancient Malmesbury slate formation, and on the denuded surface of the granite rocks; but inland, towards the North and East, as the land rises, the two succeeding great groups of strata are still found at the surface of the ground—the earlier, known as Bokkeveld Beds, occupying the Southern Karroo, and the later forming the mountains beyond, called Witteberg Beds. These older formations are chiefly composed of schists, slates, quartzites, sandstones, and shales, and, after having been folded into mountain ranges, have suffered much denudation, and this especially nearer the coast.

Then succeeded the period alluded to, as separating the older from the younger rocks, and a glacial conglomerate was formed on or near what seems to have been the shores of an inland sea, and, later, through the immense space of time which stretches from the beginning of the Carboniferous epoch through the Permian to the end of the Triassic, this sea seems to have gradually filled up—the alternate beds of sandstone and shale, full of fossil remains, pointing to long continued deposition in shallow water and subsequent elevation.

Intervals, when deposition ceased and was renewed under different conditions, have divided this great mass of strata, 6,000 feet thick, into three well-defined series, and these have been named after the places or districts in which they have been found typically developed. The first after the Dwyka or glacial conglomerate is called *Ecca Belis*, forming the Central Karroo, the next *Karoo Beds* covering the Northern Karroo, and the third, spreading over the Eastern Upland, *Stormberg Beds*.

Excepting Bechuanaland, where there are series of rocks whose relations with those in this Colony and in the Transvaal have not yet been studied and defined, these eight groups of strata form the great bulk of the part of the Continent called Cape Colony, which, save small areas in the Southern portion of the Colony covered with deposits in seas of Jurassic and more recent times, has been dry land since the middle of the Mesozoic period; that is to say, that while the greater part of Europe, including Great Britain, and much of North America, were under the ocean, and the Cretaceous and Tertiary systems of the Northern Hemisphere were in the process of forming, South Africa was dry land.

#### RAINFALL.

Whatever the climate may have been like in ages gone by, the Colony, except the country near the Southern Coast and the Transkeian Territories, does not in these days enjoy sufficient rainfall to make the excellent soil, which it generally possesses, productive. This dryness is most accentuated in the North-Western areas—in fact, the district near where the Orange River enters the Atlantic Ocean is almost rainless—and the rainfall increases from West to East across the Colony, save in the South-West corner. A series of observations, extending over many years, have been taken all over the Colony by the Meteorological Commission, which most useful work renders it possible to map out the areas of country over which different quantities of rain fall.

From these data, to give an idea of the relative dryness, it may be roughly stated that over half the Colony—which includes the Northern and Central Karroos, the North-Western Coast, and a portion of Bechuanaland—the rainfall is less than 10 inches annually; over a third, which takes in the Southern Karroo, the Eastern Uplands, and the rest of Bechuanaland, it is between 10 and 20 inches; and only over the remaining sixth, consisting of the Cape Peninsula, part

of the Coast and the Transkei, does the rainfall exceed 20 inches. This latter portion is irrigated by perennial streams and rivers; springs and streams derived from the more moist mountain districts give a supply, which serves for cultivation, to the second; but over half the area of the Colony rivers flow for only a few days in the year, and that vast tract of country which, under other climatic conditions, would be as fertile as any in the world, is practically a desert.

#### INCREASING DRYNESS.

This unhappily is not all. There is a notion abroad that the climate is growing still more dry. It is to be met with in papers and books, and in many parts of the Colony the older farmers have shewn the author where streams and rivers once ran, and told him of numbers of springs years ago yielding plentiful supplies, which are gradually falling off. Through the observations of rainfall for nearly 50 years, and by the help of other records extending over the period of 50 years before that, it can be confidently stated that there is no appreciable diminution in that respect, but there are other causes which will produce a similar effect, and doubtless the change of climate noticed by these old residents is due to them. It is evident that if vegetation, which prevents the fallen rain from immediately running off the surface and facilitates its soaking into the soil or the porous rock, is destroyed, and its journey to the nearest channel, which conducts it to a stream which leads to a river, and so to the ocean, is assisted, the country will benefit much less by rain that does fall; and practices which bring about these results *do* appear to increase year by year. One of these is the burning of the veld, so that young grass may spring up—an ancient custom of doubtful benefit to the pasturage but of positive harm to the springs; another, the destruction of forests, which, despite the strenuous efforts of the Forest Department to preserve them, seems to go on in some parts of the Colony; but the principal cause is over-stocking. The evils of over-stocking are not only the too rapid eating down of the grass but the animals, by passing over the same tracks again and again, make shallow channels for the water to run in after rains, and these gradually deepen, not only quickly carrying away the surface water but draining the ground to some extent below the surface, and water which would have penetrated into the earth or have been converted into vapour, to descend again as rain, now is hurried away to the ocean.

#### RIVERS AND LAKES.

The sources of the rivers too are in the interior, where the country becomes drier, and as the scanty rainfall there is not distributed over many days in the year, the fall, when it does come, is heavy, so that the streams, owing to the sharp slope of the land to the sea, roll in torrents to the coast, but when the floods are past their

beds soon become nearly dry channels again. They have cut their way through the mountain ranges in deep gorges and have eroded channels, sometimes hundreds of feet in depth in the lower part of their courses, so that their waters cannot be used for irrigating the lands they pass through without heavy expense in pumping. There are no lakes in the Colony, but "pans" or depressions retain fresh water for a while after rains, but these become too brackish to be of any use even to cattle before they dry up.

### SUPPLIES OF WATER.

For a country so situated, the essential factor of its agricultural development, as well as the primary need of all its communities, is water. The storage, however, of the portion of the rainfall which flows off the surface, and the utilisation of the river waters, have so many especial drawbacks in this Colony that of late years attention has been directed to the possibility of obtaining supplies from the portion of the rainfall which percolates into the ground, and experiments in that direction have met with such success that high hopes are entertained that a part of the much-needed supply can be procured from below the surface, instead of being caught upon it.

### UNDERGROUND WATER.

The advantages of naturally filtered water were so obvious that the only doubt remaining was whether it existed in sufficient volumes at depths below the surface from which it could be economically drawn. It was thought that, although there was plenty of porous rock in the Karroo formations, the position of the strata was not favourable, and that in other parts of the Colony the older rocks were not water bearing, but these theories have been proved to be incorrect. It was doubted too whether boring would tap water which would rise to the surface of the ground, but all over the country sites have been found where the necessary geological conditions obtain and excellent true artesian supplies result, sometimes spouting 15 to 30 feet above the surface, but not of any large volume. However, now that the Government possesses machinery capable of boring deeper, it is anticipated that, by employing qualified geological assistance in the selection of sites where the requisite conditions prevail, much may be accomplished, especially in the synclinal folds of the older rocks, which the small machines have not hitherto been able to reach, although it is well understood that no extensive artesian areas, like those in Australia or the United States, exist in this country. From the work done and the experience gained during the last ten years, the important and gratifying fact has been established beyond question that an excellent supply of underground water does exist almost all over the Colony.

### FLOWING WELLS.

The principal yield of flowing water has been from the Karroo Beds, which have been subjected to more recent volcanic movement, and where dolerite has intruded into fissures formed in the sedimentary crust with very little disturbance of the strata. These ridges of igneous rock are quite impervious to water and extend to unknown depths, so that they are practically underground dam-walls, cutting off the flow of water along inclined strata of porous rock, and, where these are covered by watertight beds and have also the strata immediately below impermeable, the water rises to the surface or above it. In other parts of the country also water flowing at the surface is tapped, but the occurrence of the necessary conditions at shallow depths is less frequent. However, there can be little doubt but that great numbers of sites can be selected among the folded rocks of the pre-Karoo formation where flowing water could be successfully tapped by artesian wells at greater depths than those reached up to the present time.

### PUMPABLE WATER.

With regard to water under ordinary conditions, standing in saturated porous strata, moving slowly through them, or passing by fissures, joints and cleavage planes into more open channels or subterranean reservoirs, this in less or greater quantities exists everywhere in the Colony, except over some small areas of igneous rock. In the Karroo Beds the strata are porous, the sandstones more so than the shales, to a depth of 100 feet, and then become compact and impervious. The Ecca Beds of the Central Karroo yield good supplies at depths of 50 to 200 feet, and the Bokkeveld Beds of the Southern Karroo at still greater depths, but the supplies tapped toward the coast line in the older rocks at these shallow depths are not so plentiful as in the Karroo. In Bechuanaland, the relations of the water-bearing strata are not clearly understood, as the general structure of the region has not been systematically examined, and the boring done there, although in a measure successful, has been executed without sufficient knowledge of the geological conditions, while in the Transkeian Territories a sufficient number of boreholes has not yet been put down to afford an idea of the volume and depth of the supplies. Since, however, the Ecca and Karroo series are developed there and the rainfall is far greater, there is every reason to suppose that water will be found in larger quantities than in the drier regions of the Karroo, although the igneous intrusions appear at present to cause more trouble than those more to the West.

### QUALITY OF WATER.

These underground waters are usually of excellent quality, though occasionally they are impregnated with salts or sulphuretted hydrogen

from the decomposition of iron pyrites. When, however, the gas from the latter has been evaporated by exposure to the atmosphere, the water is often drinkable: indeed, cattle have sometimes been found to prefer it to pure water, and vegetation flourishes when watered by it.

#### UTILISATION OF SUPPLIES.

The existence of such supplies of subterranean water would be of little value unless a more economical method of reaching them could be found than digging wells, but the advances made during late years in boring machinery and methods of sinking boreholes have practically solved the question, and the extensive experiments made have proved that this magnificent store of water—one of the Colony's most valuable assets—can be tapped and utilised at a cost within the means of any stock-farmer or agriculturist. The boreholes as yet put down, although admirable for the stock-farmer, are not large enough to be used for extensive irrigation. However, one of the principal improvements aimed at in sinking artesian wells is the increase of the supplies by enlarging the diameter of the boreholes and deepening the same if necessary. From the small beginnings already made in this direction developments of a highly satisfactory character are expected, which the addition of more powerful machinery to the boring plant has made possible in the future.

#### DEPTH OF SUPPLIES.

The depth at which water is struck varies considerably with the geological formation and the earth-movement to which it has been subjected, and ranges from 10 to 800 feet. Search at greater depths has not been carried on, because it is only now that boring machinery capable of sinking deeper has been provided, except in the case of one bore in the Lower Karroo, which was put down to a depth of 1,500 feet with a machine of obsolete pattern, but produced no result from which anything could be learned on this subject.

#### RISE OF THE WATER.

The water in about one-third of the artesian wells rises to the surface and sometimes above it, owing to the geological conditions being such that the water-bearing stratum contains the water under hydrostatic pressure. Some of these are the well-known conditions where porous beds, which being exposed at the surface receive supplies from the rains or rivers, are underlaid and also covered by impervious strata, and the series of strata are bent into a basin or trough with no escape for the water until boreholes are pierced through the upper impervious beds, when the pressure forces the water to the surface. Other less familiar conditions, producing a

similar result, are where the water enters the coarse stratum at its outcrop on the surface and flows down the dip of the beds, being confined to the porous strata by impervious material above and below, until it reaches an obstruction to its course, such as an igneous dyke, or a portion of strata which has graded into a more compact rock which gives no passage to the water, or a fault cutting it off by an impervious rock barrier, so that being tapped at a point where the surface is lower than at the catchment outcrop, the water rises almost to the same level as the intake. In the remaining two-thirds of the artesian wells these conditions either do not exist or are so modified that the pressure is not sufficient to cause the boreholes to flow at the surface, and windmill pumps or other means are required to raise the water.

#### WATER-BEARING HORIZONS.

The question of underground water supply has so recently received attention in South Africa that our knowledge of this great and important subject, in its relation to this country, is naturally at present limited, but as the number of artesian wells increases so will the knowledge of water-bearing horizons in the various geological formations become enlarged, so that there is a strong hope these may be determined definitely in certain regions of the Colony.

#### SELECTION OF SITES.

In most cases the selection of sites for boring is restricted, and in some there is nothing that can be termed selection at all. Water supplies for Public Buildings and Institutions are usually required on the premises, and it often happens that if the site could have been shifted a few yards a much less depth would have sufficed to reach the water; or if the position of the borehole could have been moved down the dip of the strata a short distance, flowing water would have been tapped and pumping entirely avoided. Even on farms, where the space is not so limited, the really good site is often just over the boundary fence, and it is seldom that, in picking out sites for the shallower bores, under 500 feet in depth, there is sufficient choice of ground to give an adequate opportunity of applying the principles of hydrogeology to advantage. These principles would suggest the careful examination of the surface indications—like the lines of land drainage, the existence of bush or forest which impede the flow off of the rain, the areas where percolation is probable, and the existence of springs shewing where the surplus water below finds access to the surface—before taking into consideration the denudation and erosion the original land has undergone, and the deposition of the resulting drift or alluvium; or the effect which dip, strike, and structural jointing of the stratified rocks would have on the course of subterranean drainage, and that which the position and capacity of the water-bearing formations would have on the lines of saturation.

In localities disturbed by volcanic upheaval, or by the more lateral thrusts of crustal movements due to secular refrigeration, faults and folding of the strata make the selection much more difficult and uncertain than in regions where the rocks lie more or less as they were deposited, because the faults and fissures lead the underground water in directions impossible to estimate at the surface, and often to inaccessible depths; and it requires considerable experience, allied with keen observation, to determine on favourable situations for boring. By sinking a number of boreholes in it, a practical acquaintance with a formation may be gained, which is of great value in this work, and the local knowledge of the occupiers of the land is often of assistance.

### GEOLOGICAL CONSIDERATIONS.

In the younger rocks of the Karroo, where the beds of sandstone and shale are almost horizontal and are traversed in all directions by dykes of igneous rock, the selection of sites is fairly easy, as the impervious dolerite obstructs the flow of subterranean water and encloses spaces of various areas forming underground tanks, which, if the strata have any inclination and the denuded ends of the porous sandstone beds are exposed, act as true artesian areas. An examination of the dip and strike of the strata and of the position of the walls of impervious rock point to a situation for a borehole which will drain the whole of the enclosed underground area, and, under favourable conditions, flow at the surface. But among the older rocks of the South and West of the Colony, besides the supplies nearer the surface, there would appear to be water stored in the trough-like folds, due to earth-movements, lying, however, at considerable depths, which, if it could be tapped, would require deep borings, from which it must flow at the surface to be of material value for agricultural purposes. Sites for such boreholes must not be restricted in any way, and must be placed in the position determined by a geological survey of the neighbourhood shewing the syncline in which the water is stored, and the preceding and succeeding anticlines on which the ends of the porous and impervious strata are generally exposed by denudation, and also the position of the axial bend, which makes the folded rocks approximate to or fulfil all the conditions of a basin. In like manner, if the high value of water for domestic purposes makes it worth while to pump it from a considerable depth, a geological survey must be made of the vicinity, and all available knowledge relating to the water-bearing possibilities of the formation should be collected, in order to ascertain if even a large expenditure would be likely to result in tapping a sufficient supply.

### THE "DOWSER."

These considerations are, however, in the minds of some people, of no importance, and all that is necessary is to get a man called a "dowser" or "water-finder," who possesses some faculty which enables

him to walk about with a forked twig in his hands, which twig bows itself down when the man passes over water under the ground. Moreover, if the "dowser" is exceptionally gifted, his twig, by other signs, will tell him exactly at what depth the water will be found and the quantity in gallons. As a professor in a Science College has written 428 pages on the subject, and presumably educated men, such as Noblemen, Bishops and Members of Parliament, employ these clairvoyant though illiterate men, it is not surprising that the Karroo farmer should have developed a partiality for the "dowser's" mysterious art.

#### PERCENTAGE OF SUCCESS.

The degree of success, however, in finding water achieved by the Government without any supernatural assistance in the selection of sites, has been gratifying, as about 75% of the number of boreholes put down have yielded a satisfactory supply. There is, of course, a certain element of chance in the striking of a good supply of water, which has in the nature of things to be allowed for, but which makes the work more fascinating than the almost certain methods which can be applied to the collection of surface water.

#### SIZE OF BORES.

Some 3,500 boreholes have been sunk since the first machine was imported in 1890. During the first two or three years little progress was made, but the numbers have steadily increased since then, and with the present plant about 500 boreholes can be put down per annum. These vary in depth from 10 to 800 feet, and in diameter from 2 to 6 inches. Many of these were originally put down of the smaller diameters of 2 or 3 inches and were afterwards reamed out to  $4\frac{1}{2}$  or 6 inches, when the supply of water struck was large enough to warrant it, in order to insert a deep well pump-barrel of sufficient capacity. Only boreholes in the softer formations are lined, or when the harder formations are interstratified with layers of looser material which will not stand alone. Both collar-jointed and flush-jointed tubes are used, as may be most suitable to the method of boring adopted.

#### YIELD OF BORES.

The yields of these bores vary, in relation both to the size of the hole and the strength of the supply, between 100 gallons and 100,000 gallons in each 24 hours. Generally, the water stands in the boring much higher than where it was struck, but when it does not flow at the surface it is raised by an ordinary deep well pump and a windmill, or other power. Siphons, where the configuration of the ground allows them, and suction pumps are made use of where the water rises in the borehole to near the surface, and where the drawing off or pumping does not lower it enough to interfere with the

working of those appliances. Boring is usually continued some distance below the point where the water is tapped, in order to strengthen the supply, and the pump cylinders are placed well below the rest level of the water to allow for lowering this level by pumping. Exhaustive tests of these water supplies are made, and the effect on the surface level and the quality of the water are carefully recorded, and sections of all bores, with core samples of each of the strata passed through, are preserved for future reference.

### METHODS OF BORING.

There are two principal methods of drilling vertical holes into the crust of the earth, the one more suitable for boring in certain formations or under particular conditions than the other. The older of these methods is what is called the "percussion system," known and extensively used in a primitive form in the East long before it reached Europe in the twelfth century. The essential feature of the machine employed in boring on this system is a heavy steel chisel, suspended, with weighting and turning attachments, by a rope or line of rods from a derrick above the ground, which is raised and let fall by mechanical means, so that the steel tool cuts and pulverises the rock it acts on at the bottom of the hole, and with the assistance of water poured in gradually extends the hole downwards. The debris thus detached is brought up by introducing a hollow cylinder, with a hinged valve at the bottom opening upwards, which fills with sludge and is drawn up. The chisel is then put to work again. This kind of boring plant works quickly and economically in the softer formations, but when the rock becomes hard a more effective machine is the diamond drill, introduced about thirty years ago. The active principle of this machine is quite different from that of the one first described, as by this method a rapidly revolved tool, pointed with diamonds, cuts away and abrades the rocks, penetrating gradually downwards, leaving a smooth, clean hole. As the cutting edge of the tool is annular, it cuts a clear space on the outer part of the hole and leaves a central core, which is taken out as the work proceeds, while water under pressure is pumped down the centre of the hollow boring rods, which rotate the diamond cutter, and returns to the surface outside them, having flushed the cutting tool, bringing the debris with it. In some cases, however, boreholes are of a loose and soft material in one part, in another of very hard rock, and it is necessary to employ both systems of drilling. This difficulty is overcome by fitting some boring machines with a combination of both methods, so that alternate layers of soft and hard material can be dealt with with equal facility.

A quantity of water is absolutely necessary for boring, besides that required for the boiler of a steam-power machine, and this varies from 50 to 200 gallons a day for drilling purposes, and from 100 to 300 gallons a day for the boiler, according to the class of machine employed.

## SKILLED FOREMEN.

In boring operations with any class of machine, an important factor of success is the skill of the foreman. To work on the percussion system a man must be trained to the business, just like the trade of a carpenter or blacksmith, and the foreman in charge of a diamond drill must have been trained first as mechanic, and afterwards instructed in the manipulation of the machine for a long period before he can become competent to be entrusted with such delicate and valuable tools as those used with it. The work of boring is of such a nature that delays and accidents are unavoidable, and it is only by the employment of the best machinery and skilled men of experience that they can be minimised.

## PLANT AND MACHINERY.

The boring machines used by this Government are of the following types and sizes:—

- (1) Steam-power Sullivan Diamond Drill, capable of boring a  $2\frac{1}{2}$ " hole to a depth of 3,000 feet; a  $3\frac{1}{2}$ " to a depth of 2,000 feet; or a  $4\frac{1}{2}$ " hole to a depth of 1,000 feet.
- (2) Steam-power Diamond Drill, capable of boring in solid rock to a depth of 600 feet a  $2\frac{1}{2}$ " or  $3\frac{1}{2}$ " hole, which can be reamed out to  $4\frac{1}{2}$ " if required.
- (3) Hand or Horse-power Diamond Drill, capable of boring, to a depth of not more than 400 feet, a  $2\frac{1}{2}$ " hole, which can be reamed out to 3".
- (4) Combined Percussion and Hand-power Diamond Drill, boring, in loose formations, to a depth of about 300 feet, holes from 2" to 6" in diameter.
- (5) Steam-power Percussion Drill, capable of sinking, in softer formations, a 6" hole to a depth of 400 feet.

No. (1) is a powerful plant, consisting of a boring machine, line of rods, hauling gear, force pump, engine, boiler, and derrick 60 feet high. An important feature is the hydraulic apparatus for regulating the feed down, or rate of cutting of the diamond tool. The boiler is 15 horse-power, and the vertical engines, boring machine, feed gear, and hoisting apparatus are comprised in one machine, but each can be operated separately. The steam pump is of necessity separate, but stands beside the machine, and is connected with the hydraulic feed, as well as the boring rods. The machinery stands directly beneath the derrick, the four legs of which enclose a galvanised iron house, to protect it from the weather. Although the plant weighs 21 tons in all, it is fairly portable, and can be moved from place to place with ease, but as the deep holes for which this apparatus is employed take some time to drill there is no necessity to shift it often.

No. (2) is a much smaller steam plant, consisting of a boring machine, force pump, derrick, and line of rods. The engine is

attached to a vertical boiler mounted on wheels, and fitted with a "disseboom" for draught purposes, and the rest of the gear can be loaded on an ordinary wagon.

The Hand or Horse-power Diamond Drill, No. (3) is made up of the same parts—with the exception of the engine and boiler—as the steam-power, but the whole is of a lighter make, and is driven by means of a crank handle or horse-gear.

The combined plant, No. (4), is made up by adding to the Hand-power Diamond Drill monkey weight, lifting jacks and other gear for driving and drawing lining tubes, and cutting chisels, sinker-bar, and all appliances necessary for working on the percussion principle.

The Steam-power Percussion Machine, No. (5), is characterised especially by its portability. On a wagon-frame, with wide-tired wheels, is mounted a boiler and engine, a walking beam to give the best motion for drilling, a hauling gear, a steam pump, a pipe driving attachment, and a derrick; and the whole can be drawn over the roughest roads by inspanning a small team of oxen or horses. It is necessary, however, if the roads are bad to carry the heavy steel chisels, sinker-bars, recovery tools, and other detachable gear, in another wagon. The arrangement of the frame and working parts is such that the foreman can stand at the tools while drilling, or while cleaning out the debris from the bore hole, and at the same time reach the throttle valve, so that he can regulate the speed of the engine as circumstances may require. The derrick is of the folding-ladder pattern, and answers the purpose very well for bore holes not deeper than 400 feet, to which depth the strain is not so great as to necessitate a built derrick.

### DIAMONDS.

An extremely important matter in connection with boring for water is the construction of the tool edged with diamonds, or crown, which is used with the diamond-drilling machine, and which is essential where hard rock is met with, and under circumstances where it is necessary to secure a core to shew the section of the geological formation passed through. The diamonds employed in this work are obtained either from the mines in Brazil or from those in South Africa. The black diamond, or Brazilian Carbonado, in composition nearly pure carbon, is the hardest substance known, and is used for piercing the densest rocks, such as quartz and dolerite, but several kinds of Kimberley brilliant and boart are also made use of, as they work very well in the less compact rocks and are not so costly as the Brazilian stones. Diamonds of pure water and good shape, such as can be cut for ornamental purposes, are not as a rule used for boring, hardness and freedom from cleavage planes being the qualities most needed. Suitable stones could be purchased at reasonable prices in the earlier days of diamond drilling, but now this industry has reached such large dimensions that the better class of drilling

diamonds fetch more in the market than those used for decorating the person, and even Kimberley diamonds, since the war, have not only advanced immensely in price but have become scarce.

### SETTING CROWNS.

The steel crowns, or bits, in which the diamonds are mounted, vary in outside diameter from 2 to 6 inches, and in length from 3 to 6 inches. They have a female thread for attachment to the barrel in which the core cut is carried, and are set alternately on the outside and inside of the cutting face, which is  $\frac{3}{8}$ " to  $\frac{5}{8}$ " in width, with six, eight, ten, or twelve stones, according to the size. The insides of the crowns are tapered, so that an annular hardened steel ring, grooved and bevelled, placed in the larger space, more remote from the cutting face, between the tapered inside of the crown and core of rock cut by the diamonds, will, if the crown and core barrel be lifted out by the boring rods, grip the core, break it off, and bring it up. Reamers for enlarging boreholes are similar in construction to the crowns, except that the reamers have a slightly wider face and have guides projecting, to ensure their filling exactly the borehole which is being reamed. The steel of the crowns is found to wear most in sandstone, and diamonds boring in that rock require frequent resetting, for should a stone become loose and drop from its mounting, the crown will rotate upon it and quickly break the rest of the diamonds. The actual wear of the diamonds is considerable, and the harder the rock the more wear they sustain. The loss by breakage, however, is generally due to unequal density of rock, such as is met with in the formations which have fine veins of quartz infiltrated in them, or are of the nature of a conglomerate. All crowns and reamers are set and dismounted, at the shop for that purpose in Cape Town, by skilled and experienced diamond setters, and are despatched by registered post to the boring operations all over the Colony.

### COST OF BORES.

The cost of boring is a most difficult matter to state. Boreholes vary in depth, size, and hardness of the material pierced, and many of them have to be lined with iron tubes when the ground is too soft or loose to stand alone. The value, too, of the skilled foreman's services, of machinery, diamonds, transport, and all the other items which go to make up the cost, fluctuates considerably. And, again, the conditions under which the work is undertaken greatly influence the cost. The want of modern and economical machinery, or a disturbed political and commercial state of the country, will prevent the carrying out of the work in the minimum of time. Wars, cattle diseases, droughts, or interrupted railway services, cause endless delays, and paralyse every effort at economic organisation.

The past five years of boring work have unfortunately embraced almost every factor calculated to retard economic operations and divert funds from their legitimate channel; and it is beyond question

that, under happier auspices and more advantageous circumstances, expenditure, which by no means appears large, may be further reduced. Another difficulty is that some of the items which make up the full cost, such as Kafir labour, fuel, water for drilling, and wagon transport, are not supplied by the Government, and consequently reliable accounts of such expenditure cannot be kept. An approximate figure may, however, be arrived at by taking an average over a large number of boreholes put down during a long period, which figure, of course, must be understood to apply to the cost of a large number and not to any single one or small number of artesian wells. Roughly, it may be stated that 2,000 boreholes between 10 and 800 feet in depth, and varying from 2 to 6 inches in diameter, put down by this Government during the past five years have cost on an average £50 each. The cost per foot varies from 4s. to £4, and no average price can be stated that would in any way be of value to either the general public or professional men.

#### RESULTS OF BORING.

Artesian wells have been put down in nearly every division of the Colony, Namaqualand, Bechuanaland, and the Transkeian Territories, with success, and from the experience thus gained it may be safely deduced that an excellent supply of underground water exists almost all over the Colony, at a reasonable depth, which, being tapped by boring, flows at the surface or can be utilised by means of an ordinary deep well pump, and, moreover, at a cost within the means of nearly every farmer. Although the wells yet bored are not large enough to permit of any extensive irrigation, agriculturists are only too glad to make use of them for the high cultivation of small areas, as is evidenced by about a thousand acres of garden ground, orchards, and lucerne fields, irrigated from boreholes in different parts of the Colony. To the stock-farmer, however, they are a source of prosperity and wealth, as the supplies already met with are amply sufficient for watering stock. The loss by drought by this means can be absolutely avoided, and by tapping supplies in different parts of a farm its stock-carrying capacity can be considerably increased. Were there any question regarding the results of boring for water, the great, nay, overwhelming, extent to which owners and occupiers of land have availed themselves of the facilities afforded for obtaining a good water supply from underground sources would loudly testify to the value and beneficial character of the results achieved.

#### PUBLIC BUILDINGS AND VILLAGES.

The advantages of this mode of obtaining supplies of pure water for gaols, asylums, court-houses, and other public buildings, soon became apparent to the Government, and at many of these buildings in different parts of the Colony the successful boring operations carried out have been the means of effecting a large economy in charges consequent on the substitution of boreholes for other and

more costly methods of supply; and, further, it has been the means of improving the quality of the water used for drinking purposes. This source of supply is also being utilised for the water supply of small towns and villages, where its importance in yielding pure supplies of water, and thus eliminating the danger to public health from water-borne disease, is being recognised.

#### PRESENT POSITION.

The present position, then, with regard to a water supply from underground sources for the Colony is briefly this. Just beneath the surface of the ground is stored a supply of water which, if utilised, would be an important factor in the development of the industries of the country and ensure its material prosperity; and, further, it has been proved that this water supply can be put on the land at a very reasonable cost. As it is extremely doubtful if any other part of South Africa possesses such ample supplies under the same conditions of accessibility, the valuable nature of this resource is apparent, and the desirability of proceeding to take advantage of it becomes obvious to any one interested in the progress of this Colony. The question, then, arises as to what extent this source of water supply can be made use of. Unlimited it cannot be, as water is not manufactured in the earth but comes from the atmosphere above, so the rainfall must be considered.

#### RESERVES OF UNDERGROUND WATER.

The distribution of the annual rainfall over the area of the Colony not only varies in quantity but also in season of the year, a greater part of the country enjoying summer rains, and only that portion on the West and South receiving winter rains. The annual quantity in the North-Western districts is small, but as it increases towards the East and South considerably it is possible that the rocks of the drier districts contain more water than actually falls on the ground immediately above them; in fact, the movements of underground water, as far as they are known at present, would seem to indicate that water travels immense distances in the crust of the earth, descending by the faults and fissures of a formation in one part of the country and ascending by other channels, in different strata, in quite another region. In view of this possibility, and of the fact that the rainfall, although only 10 inches over a half of the Colony, ranges up to 30 inches over the rest of the country, it would not appear to be making an exaggerated estimate of the quantity which percolates into the ground and feeds the reservoirs of water in the rocks if  $2\frac{1}{2}$  inches be taken as the average all over the Colony. Assuming this calculation to be correct, the part of the annual rainfall which feeds the subterranean reservoirs amounts to a daily quantity of 27,715 million gallons, whereas the total quantity now daily drawn from it by all the boreholes put down up to the present time is not more than 25 million gallons, so that no efforts of ours need be limited by any fear that the general reserves of underground

water will run short; in fact, these are so large that what has been done in tapping them, by comparison, appears only a small beginning.

#### FUTURE OPERATIONS.

If this is so, the many advocates of this method of water supply will naturally say that "every farm should have its boreholes," to which there would be no objection as far as the supply of water available is concerned, as most farms have an extent of more than a square mile—an area capable of yielding 100,000 gallons per diem. It is, however, on account of the number of farms in the Colony, perhaps 100,000, that such a scheme can only serve as an ideal to work up to in future years, but still, to make any appreciable difference in the productive power of the stock-farming and agricultural industries, the water supply of at least 5,000 farms must be improved in the immediate future. Already 1,000 farms are on the books to be dealt with as soon as facilities become available, and there must be added a number of villages where no wholesome water supply at present exists, which cannot be neglected, and hundreds of institutions where the underground water is the only safe source of supply available; and as each farm requires two or three boreholes it can be readily seen that it is necessary to undertake the sinking of a minimum number of 10,000 boreholes at once if this Colony is to keep abreast of the other Colonies of South Africa (which are about to expend large sums on irrigation works) and develop her agricultural and pastoral resources, while an era of great prosperity reigns and high prices rule. These borings will average about £50 each, so that, if the opportunity of establishing the industries on a sounder basis is to be embraced the expenditure of a sum, say, of £500,000, will have to be faced for the carrying out of this work during the next two or three years, but with a definite scheme for the refund of a large part of the expenditure.

#### STATE AID IN THE PAST.

Hitherto, as is well known, State-aid has been granted in tapping supplies of underground water to assist the stock-farming and agricultural industries, as these have suffered from drought, disease, and the disturbed state of the country more than any other industry, and it has been appreciated, judging from the immense number of applications registered. The exact amount of this assistance has varied in accordance with the circumstances and cost of the work, but is at present practically regulated on the £ for £ principle. Later, however, when the farming industry recovers its prosperity, which it is bound to do with the finest market of the world in its midst, perhaps a larger contribution may be expected from it. The regulations now in force have applied to comparatively shallow boreholes, but now, as the Government is in a position to bore deeper, a differently proportioned State-aid might be introduced, which would bear fairly on the landowner benefited and the taxpayer.

Under the present system the Government supply machinery and material and skilled labour, and the farmer transport and rough Kafir labour. This method has acted very well, as the cost of the boreholes has not been great, and in the event of failure to obtain a supply the loss sustained by the farmer has not been heavy; but in boring deeper holes the cost will become too heavy a loss for the farmer to bear if unsuccessful, while success would unduly enrich him at the expense of the taxpayer. He should, under these circumstances, at least pay the whole cost of the work, which has probably increased the value of his property ten times. An equitable plan would be for the Government to select sites where there appears to be a probability of tapping supplies of artesian water, and enter into an arrangement with the landowner to bore the hole. The agreement should be that if the borehole yielded over a certain quantity of water under certain conditions, he (the landowner) should repay the full cost in instalments, extending over a period of 5 or 10 years, but that if no adequate quantity of water were found Government should bear the greater share of the cost. There would seem to be few difficulties in the way of carrying out such a scheme, which would encourage enterprise in the agricultural industry very considerably; and as the proportion of successes is far larger than that of failures, the refunded amounts would probably be largely in excess of those chargeable to the Government. With Municipalities and Public Institutions paying full cost of boring, and a large refund from the farming industry, the net cost to Government would not be a great part of the £500,000 required, 30% perhaps, and the ample reproductiveness of this expenditure in increasing other sources of revenue should recommend it as an outlay which would be repaid indirectly in the course of a very few years.

#### REFUND OF STATE-AID.

The enormous possibilities latent in the development of this source of water supply, and the resulting appreciation in the value of land benefited by the use of the underground water, more than promise that a step further may be taken in the direction of refunding the cost of sinking artesian wells advanced by the Government. Many landowners assess the increase in value of a farm on which a good boring has been made at 100% per morgen, but on some properties it is much more after a good supply of flowing water had been tapped, sometimes ten times its former value; but, estimating the increase in value to be only 50%, an average sized farm of, say, 500 morgen, previously worth £500, would realise £750, and if the borehole costs £50, the enhanced value, directly due to it, would be £200. As there are some 100,000 square miles of the Colony as yet undisposed of, it is almost certain that good sites for boring could be selected on 1,000 Government farms where water was much needed, and the execution of the work would produce an increase in the value of the land equal to a sum which would pay off the amount not refunded by the agricultural industry, as well as the charges for

interest on the whole expenditure for boring work, and so relieve the taxpayer of all incidence. Without the actual expenditure of public funds, but by simply making use of its own splendid asset, the like of which no other country is fortunate enough to possess, the Colony would receive such material benefit that its future prosperity would be assured.

#### BORING FOR THE MILITARY.

It may be of interest in reviewing the uses of underground water to refer to its importance in connection with Military operations, as it proved of great value during the recent campaign in this country; and some account of the methods employed and the results obtained—the bulk of which has already appeared in the Annual Reports of the Department—may form a fitting conclusion to this paper:—

Having, prior to the outbreak of hostilities, executed some boring for the Imperial Government at one of the Base Camps near Cape Town, the Colonial Government was, soon after the War broke out, approached with a request that it (the Colonial Government) would undertake the sinking of boreholes to provide water for General Gatacre's Division, which was at the time at Stormberg, in response to which the Colonial Government immediately caused three boring plants, equipped with two foremen each for continuous working, and a field superintending inspector, to be placed at the disposal of the Military Authorities for service in that Division. Excellent supplies of water were obtained for the Column while in the Stormberg District, while subsequently, during its march into the Orange River Colony, two out of the three boring plants, fully equipped, accompanied the Division, with the result that plentiful supplies of water were obtained at various points en route for the purposes of Camps, Military Posts and Hospitals. Meanwhile, another plant had tapped a large supply of water at Rensburg Camp, and at other positions in the surrounding country occupied by General French's Cavalry Division. A little later, when the Modder River became contaminated after Lord Methuen's reverse at Magersfontein and enteric fever broke out among the troops lying there, two more fully equipped steam plants were despatched to those Camps, and, working without intermission, obtained an excellent supply of pure water within 30 hours of their arrival. Boreholes were also put down in the course of the following week at Enslin, Graspan and Belmont, not only with the object of providing those Camps with water, but also in order to meet anticipated requirements of the main Army under Lord Roberts on the forward movement. These subsequently rendered immeasurable assistance to the Army under the Field Marshal during the operations which resulted in the relief of Kimberley and the capture of Bloemfontein. Without water for the transport animals employed by the immense convoy following the Army, the execution of the gigantic Military operations involved—the essential feature of which was rapidity of movement—undoubtedly would have been seriously nampere. To meet the large demands of the Army while resting at Bloemfontein prior to the resumption of the advance North-

wards, additional boring plants were forwarded to that town, as many as eight operating there at one time, and it is worthy of note that during the possession by the enemy of the Water Works at Sanna's Post supplying the town, water obtained by means of boreholes was pumped into the street mains of the City. Boring plants subsequently accompanied the Army during its march to Pretoria and during various operations Northwards and Eastwards, a boring plant even accompanying the Column which cleared the country to the Portuguese frontier. General Tucker's Division depended entirely on the boreholes at Karee Siding, the only other source of supply being unsuitable, owing to surface pollution. Boreholes were also sunk to the North of Kimberley and proved of great assistance to the operations in that direction, which culminated in the relief of the gallant garrison of Mafeking. In the Transvaal a number of boreholes have been put down, but at most of the sites the geological formation consisted of volcanic rock and only a small measure of success was obtained. In the Orange River Colony, however, Camps, Hospitals and Blockhouses have been extensively supplied with good drinkable water, particularly in the neighbourhood of Bloemfontein and Kroonstad. Boring has also been of service inside the defences of Steynsburg and Middelburg, and at the Refugee Camp at Aliwal North; and when the difficulties of suppressing the Rebellion in this Colony made it a military necessity to build a line of Blockhouses across the Karroo, from Victoria Road on the Western line of Railway to Lambert's Bay on the Coast, a distance of 400 miles, boring had to be resorted to, in order to enable the construction of the work to be proceeded with, as, owing to the arid nature of the country, supplies of water on the route selected were extremely scarce. Consequently, at the request of the Military Authorities, strong parties of foremen, with all the boring plants then available, were despatched by this Department to either end of the proposed line, and work commenced early in January, 1902. No effort was spared to keep the boring work in progress without intermission during the hours of daylight—work at night being impossible owing to Boer snipers—and, although surrounded by the danger from constant attacks of small parties of the enemy, the foremen and men worked with so much will that over 100 boreholes were put down, and excellent supplies of water furnished all along the line by the beginning of June. The number of feet bored amounted to 6,000, each plant making an average of 10 feet a day, an excellent record under such exceptional circumstances. The average yield of each borehole was from 8,000 to 18,000 gallons per diem, and the total quantity of water, of an excellent quality, available by pumping or flowing at the surface, amounted to 900,000 gallons per diem.

#### GRATIFYING RESULTS.

In all, it may be mentioned, some 251 boreholes have been executed for the Military Authorities at various Camps, Forts, Military Posts and Hospitals in Cape Colony, the Orange River Colony and

the Transvaal, with a total of 16,000 feet bored and an aggregate daily yield of nearly 2,000,000 gallons. The value of these supplies of pure water thus provided for the Army in the field, and for the troops guarding the Lines of Communication, cannot be overstated in a country like South Africa, with its subtropical climate and comparatively waterless character, the purity of the source of supply having, moreover, a most important influence on the health of the troops, since much of the enormous sickness the Army experienced was due to the consumption of water from contaminated streams and surface sources. The immense advantage of being able to procure naturally filtered water is so apparent that the assistance rendered in this direction by the Colonial Government undoubtedly saved many valuable lives to the Empire, and contributed not a little to the success of the campaign. This is the first time in history that boring for water has been a feature in military operations, and the inestimable value of the results which have followed its adoption in the late campaign will undoubtedly lead to the Water Boring Machine, in qualified hands, becoming a factor of prime importance in any future wars in which the theatre of operations presents difficulties in that direction such as faced the British Army in South Africa. Moreover, a scheme has been formulated for forming an Imperial Military Water Boring Department, in which the author suggested the necessary details for an organisation by which boring for water could be carried on during campaigns in any part of the world. It is, under the circumstances, gratifying to learn that not only have the advantages derived from the underground supply proved of vital importance to the welfare of our Army in the late War, but that there is a strong hope of the experience gained being utilised by the War Office and a thoroughly trained Water Boring Corps formed, which would, by facilitating Military operations, add efficiency to the British Army, and, by lessening the death roll of our soldiers by sickness, gain the appreciation of the whole nation.

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### 35.—CURVED CONCRETE RESERVOIR WALLS AS CONSTRUCTED BY THE PUBLIC WORKS DEPARTMENT OF NEW SOUTH WALES.

BY WILLIAM CRAIG, A.M.INST.C.E.

During a recent visit to Australia the writer was much impressed with a number of Reservoir Walls which had been constructed on the curved or arched principle on the designs of Mr. C. W. Darley, M.I.C.E., formerly Engineer-in-Chief to the Public Works Department, New South Wales, from whose valuable paper on this subject—read before the Engineering section of the Royal Society of New South Wales in December, 1900—and through the courtesy of his successors in the Department, the following particulars have been obtained.

After several Walls had been successfully constructed on gravity sections by the Department, it became necessary in the case of smaller towns, where the cost of a gravity section was prohibitive, to design a more economical form of Reservoir for storage purposes, and, guided by the success which had been attained in America and elsewhere of building Walls on the curved principle, the Department decided to adopt that system whether the site selected proved favourable for such construction.

The conditions necessary for the adoption of the curved wall in place of a gravity section are (1) the selection of a comparatively narrow gorge or river channel, (2) solid rock foundation throughout and (3) rock slopes on either side for abutments. The third condition has not always been found practicable, and in such cases the arched section abuts on a wall of gravity section which answers the same purpose.

There are now seven curved concrete Reservoir walls in New South Wales with radii varying from 100 feet to 300 feet, all of which have been designed on the following principles (extract from Mr. Darley's paper):—

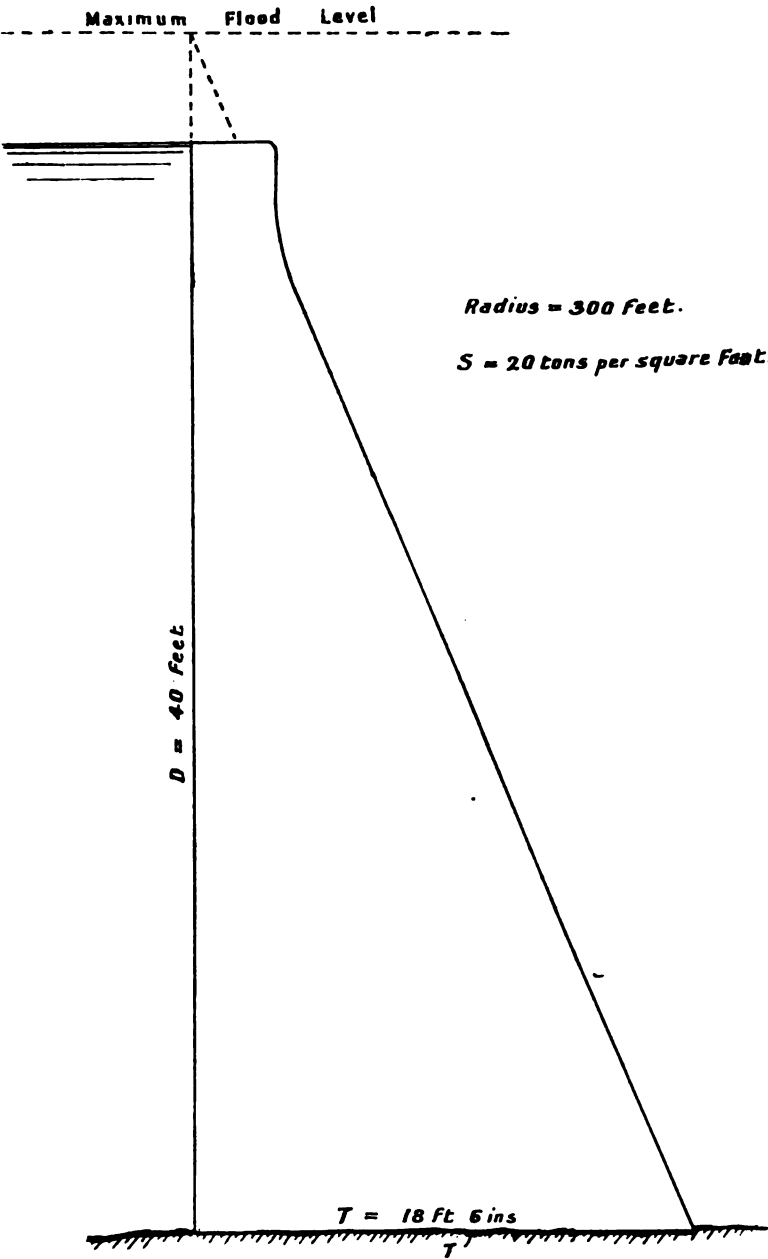
“A curved dam with solid rock abutments being subject to the same stresses as a hollow empty vertical cylinder of the same radius and surrounded on the outside by water of the same depth as that impounded by the dam, the formula for resistance of cylinders to a crushing pressure, viz.,  $P = \frac{2T}{R}$  or  $\frac{T}{R}$ , has been used for calculating the thickness of the wall

where

P = Water pressure in tons per square foot.

T = Thickness at any point in feet.

R = Radius in feet.



$D$  = Depth of water to be impounded, which should be calculated from the maximum overflow or flood level.

$s$  = Safe crushing strength of material per square foot. This varies from 20 tons for granite or basalt abutments to from 10 to 12 tons for sandstone and other similar formations.

For convenience of construction the inner face has been kept vertical, while the outer face has been battered (as shown on the accompanying drawing). The flood water passes over the crest of the dam—no special provision being made for its discharge, except in cases where the catchment area demands it.

The thickness of the wall at any depth is calculated from a simple diagram in the following manner:—

$$P = \frac{D \times 62.5}{2240} = D \times .027902.$$

$$T = \frac{R.P.}{s}.$$

$$T = R.D. \times .0014 \text{ when } s = 20 \text{ tons.}$$

$$\text{and } T = R.D. \times .0023 \text{ ,, } s = 12 \text{ ,,}$$

Although the theoretical cross section of the dam would form a triangle having its apex at top water level, it is the usual practice to increase the thickness at overflow level from 3 feet to 5 feet, according to circumstances, as in most cases the walls are liable to shock from floating timber during floods.

In calculating the cross section the weight of the wall itself has not been taken into account, although, of course, it is a considerable factor on the safe side.

*Construction.*—The methods of construction are of the simplest, and the writer had an opportunity of seeing the work at Wollongong while the foundation courses were in progress.

The work is carried out departmentally for the reason that it is not always possible to determine the actual depth of foundations from trial pits, and contractors' claims and disputes are avoided. The workmen employed under the Resident Engineer are used to this class of work, and a more uniform standard of construction is obtained.

It has also been found that the work can be carried out departmentally quite as economically as if done under contract, and so far the Department has had no reason to depart from this course.

*Foundations.*—All loose or shaken rock is removed, and all smooth or inclined surfaces are stepped and roughened. It is not usual to cut a trench for the foundations where the surface rock is fairly uniform, but the whole of the base is well washed with a jet of water under a pressure of about 20 lbs. per square inch, and all joints or fissures are raked out and grouted with cement mortar.

Over the whole surface a half-inch layer of mortar is spread, well worked into all corners and recesses, and the first layer of concrete is deposited thereon while the mortar is still fresh.

*Framing.*—The wall is carried up in 3 feet courses, which are deposited in 12-inch layers, each somewhat ahead of the other. The frames used are 10 feet long by 3 feet 6 inches high, and sufficient frames are provided to carry a course the full length of the dam. These frames are held in position by profiles, which, as the wall rises, are secured thereto by means of bolts, with nut at each end, built into the wall and spaced at intervals of 10 feet horizontal and 3 feet vertical. When a course is completed the bolts are unscrewed, leaving the inner nut in the wall, and the profiles and frames are lifted 3 feet, leaving a 6-inch overlap on the completed course. The bolt holes in which the nuts remain are filled with mortar as soon as the framing is removed.

The frames on the up-stream side are curved to the mean radius of the face of the wall, while on the down-stream or battered face arrangements have to be made for the increasing radius as the work is carried up.

The concrete after being mixed is conveyed to the wall on a narrow-gauge tramway, which allows of the skips passing between the mould boards on the thinnest part of the wall, and is dropped therefrom into position.

*Materials.*—The proportions of the ingredients of the concrete used in the body of the wall are as follows:—

4½	cubic feet of cement.
12	" " " sand.
10	" " " shivers, ½-inch gauge.
13	" " " metal, 1½-inch gauge.

On the up-stream or water face of the wall a 6-inch facing is deposited of the following proportions:—

4½	cubic feet of cement.
10	" " " sand.
10	" " " shivers, ½-inch gauge.

Plumstones to the extent of one-third of the total bulk are used, and in no case does the size exceed that which can be handled by two men. They are bedded in the concrete with their thinnest edges downwards, and the concrete is well rammed in between each stone. The plumstones project above each course as finished, so as to form a key for the next course.

When the frames are removed from each course, and while the concrete is still green, the whole surface is floated over with neat cement, which forms an impervious skin on both faces of the wall.

*Scour and Supply Pipes.*—A cast iron scour pipe of about 24 inches diameter is placed in the lowest portion of the wall controlled by an ordinary sluice valve.

The supply pipe is controlled by a valve from the outside, and on the inside a galvanized wrought pipe is connected thereto by means of a trunion joint, which admits of the pipe being raised or lowered by means of a crab winch so as to draw off the water as near the surface as may be desired. These pipes are provided with galvanized wire netting screens at the end, and when the pipes are drawn up to the vertical position these screens can be readily cleaned or renewed.

*Cost.*—The following particulars of cost of actual construction are given as a fair average over the seven dams which have been constructed by the Department:—

Sand-washed... ..	5s. 6d. per cubic yard.
Rubble quarrying ... ..	4s. 10d. per cubic yard.
1½" metal and ½" shivers ... ..	8s. 7d. per cubic yard.
Cement (local manufacture) ...	16s. 2d. per cask of 4½ cubic ft.
Tradesmen ... ..	12s. to 13s. per day.
Labourers ... ..	7s. per day., min.

The total cost of concrete work, with about 33 per cent. plumbstones, as measured on completion of the dam, is found to average about 30s. per cubic yard.

### 36.—NOTES ON THE PROGRESS OF SURVEY OPERATIONS IN SOUTH AFRICA.

BY SIR DAVID GILL, K.C.B., LL.D., F.R.S., HON.F.R.S.E.

[NOT PRINTED].

## SECTION D.

### 37.—PRESIDENTIAL ADDRESS.

BY THOS. MUIR, C.M.G., M.A., LL.D., F.R.S.

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#### EDUCATION AND SCIENCE.

So long as the sections of a Science Association embrace a multiplicity of subjects the appropriateness of having an introductory address which aims at a general treatment of the whole must remain questionable; and it will, of course, be all the more questionable if the subjects be arranged on any other principle than that of family relationship. In the early days, however, of such an association, one must recognise the impossibility of specialising to the extent attained in more populous centres of civilisation, and adapt oneself as well as may be to meet the claim which custom demands. I, therefore, take on the one hand from among the subjects of the section one which all men will grant the importance of, viz., Education, and then place on the other hand not merely all the other subjects of the section, but all the subjects of all the sections, viz., Science, and ask you to consider with me for a few minutes the signs of the times in regard to the two, the influence of Science upon Education, and the attitude of Education towards Science.

If we cast over in our minds the principal events of the recent history of education in England it is not difficult to separate out three main streams of tendency; and as all such streams are in no sense the products of chance or artificial stimulation, but have to be viewed as the natural results of the operation of forces acting in accordance with the laws of evolution, it would be a fatal mistake anywhere to neglect the study of them. The mistake would, further, be all the greater if made in lands which have not yet reached the same stage of progress as England has, and which, therefore, have still the same thorny road to travel as she has toiled through. First of the three I place the tendency to *Modernisation*. The old curricula have been under a steadily increasing fire of criticism; the old methods of teaching have been held up to ridicule; and the old Boards of Management have been treated with scant respect. What thus began in fault-finding developed into the drafting of schemes of reform, into the formation of associations for promoting those schemes, and ultimately in numerous cases into modification of the statute-book. We have only to think of the altered attitude towards such subjects as wood-work and cookery in elementary schools; the change in position of French, German, and Science in secondary schools; the initiation and development of separate schools for technical education; and the great widening of the curriculum in Universities;—we have only

got to do this to be conscious of the character of the powerful movement which was and is in progress. The story of technical education alone would suffice to bring conviction. Prior to 1887, were the years of criticism and individual effort; in July of that year the "National Association for the Promotion of Technical Education" was formed; then came two years of agitation and abortive attempts at legislation; the consummation of this was the passing in the year 1889 of the Technical Instruction Act, conferring upon County Councils and certain other bodies the power to levy a rate for the purpose of promoting technical instruction; in 1890 the subject was recognised in the elementary education code; 1890 was also the year of the fortunate accident by which the unappropriated residue of the beer and spirit duty was given over to the County Councils for the same purposes as the proceeds of the rate of the Act of 1889; the year 1891 saw the foundation of the London Polytechnics; and year by year since then the number of technical subjects dealt with by the bodies concerned has increased in a remarkable degree, even including the constituents of what would at one time have been differentiated as "commercial" education, "technological" education, and so forth. Alarming sums have been annually spent, and many are the schemes which different councils have inaugurated, and proved to be not wholly effective; but yet the movement as a whole shows no sign of slackening. The same tendency, though less pronounced, is evident in connection with University education, and might be illustrated quite similarly. Let one fact alone be given; it will be ample for any one who can look back to the predominant importance once assigned to the classical languages in university curricula, and to the pitying scorn with which the early opponents of this predominance were met:—*the new University of London* (a now by no means unimportant corporation) *welcomes undergraduates who have no knowledge of Latin at all.* The modernising stream, in fact, would seem to widen as the years advance. "Nature study" has quite recently been edged into the Code of the Elementary Schools; and "brewing" and "commerce" have been honourably entered on the curriculum of a university which in more points than this prides itself on being "modern."

The next of the tendencies observable in English educational history is towards *Organisation*, and it may at once be remarked that no prominent country of the world has stood more in need of a change in this direction. Up almost to the middle of the nineteenth century there was chaos in every division of English education: and even in 1846 when the first step towards reform was taken, it was only *elementary* education that was thought of. The idea of a country's education being an organic whole, and requiring treatment as such, had crossed few men's minds. Although, therefore, the next fifty years brought great developments in elementary education, the Department controlling it took no cognisance of other branches, save in so far as to add to existing confusion by the formation of "higher-grade" schools. Then simultaneously with this growth, there was a like

expansion of the work entrusted to the guardians of the old "schools of design," the result being the full blossoming of another department, the Department of Science and Art,—a department always conscious of its good deeds and therefore proud of its separate existence. As for secondary education, reforms, though coming late, came in fair quantity after the passing of the Endowed Schools Act of 1869; but a third separate executive body was called into existence by that Act, viz., the Endowed Schools Commission, later the Charity Commissioners. It has to be remembered, further, that secondary schools existed beyond the control of those Commissioners, and that the full extent of the confusion in the management of secondary education was not even approximately known until a much later date. Stranger still, when an entirely new branch of education had to be attended to in 1887, viz., technical education, none of the local educational bodies already in existence were entrusted with it, but, as we have seen, it was handed over to the Councils established by the Local Government Act of 1888. Sooner or later the various authorities thus created were sure to come into conflict; and the greater the activity shown by them individually, and the greater the outside demand for educational development, the sooner would the clashing of the interests become intolerable and action towards unification become necessary. During the last decade of the century this stage was reached, and people and Government both felt that an epoch-making step had to be taken. After the usual vexatious delays an Act was passed in 1899 creating a Board of Education to take the place of the Education Department, the Science and Art Department, the Charity Commission, so far as its educational work was concerned, and even the Board of Agriculture to the same extent. Great as this measure must be viewed, it was only the prelude to a greater, viz., the Education Act of 1902. While the former unified the Government departments dealing with education, the latter may be said to aim at ultimately bringing about a like unification of the local authorities. In view of the many diverse interests involved, a perfect unification was hardly at first possible; but much has been done by it towards placing all education, save University Education, under the local control of the County and Borough Councils. The Act is only a few months old, and we cannot therefore look for results; but it is not too much to say that almost all educationists who can hold themselves aloof from ecclesiastical and political partisanship have high hopes of good from it, and look forward to improvements upon it in the future.

The third tendency which claims attention is the tendency towards *Nationalisation*. Fortunately, it is so bound up with the second that a few additional words will suffice for it. So late as the early part of the nineteenth century the English State seemed unconscious of having any direct duty in regard to the education of its people. The providing of schools was apparently held to be the work of religious and philanthropic bodies, or a matter to be left to private enterprise. Wiser views must have been in circulation by the time (1830) a separate Department of Education came to be created:

but the fully developed principle that the State must insist upon the education of children, even in the teeth of opposing parents, had no legislative hold until the year 1870. In 1880 the hold was strengthened; and since then the principle has branched out in several fresh directions. The State has come consciously or unconsciously to be looked on as a living organism, subject to evolutionary laws, and therefore compelled to fit itself for survival in the struggle for existence. Punishment for neglected opportunities follows swift upon nations as upon individuals; and possibly the fear of punishment has done more in England to hasten educational progress than any belief in the value of philosophic foresight. What originated the Science and Art Department? The fear that the artistic designs of Continental manufacturers would cripple certain branches of English trade. What led to the Technical Education schemes of 1889 and 1890? An identically similar fear. Why are we hearing now daily of fresh schemes for education in the Army and Navy? Because of the lessons of the late war, and because of rumours of war to come. In the case, however, of the great nationalising Act of 1902, which is implicitly founded on the principle that all elementary, secondary, and technical education is the immediate concern of the State, no such direct cause is traceable, and we may well hope that the principle was explicitly before the minds of all those concerned in the passing of it.

Now, looking back upon these three tendencies, and reflecting upon their character and history, it is impossible to doubt the assertion that nothing has contributed more to the development of them than the immense growth and diffusion of science. On every side social and national life are enveloped and affected by scientific discoveries; and the rapidity with which a purely theoretical result is forced to yield a practical application has become a matter of everyday experience. Our environment is daily changing because of scientific advance; we cannot live in the past even if we would. Hence the modernisation which has already taken place in the curriculum, and the persistent, not to say irritating, call for further practicality. Hence also the recognition of the national duty in regard to education, as has just been pointed out. Even the pressure for organisation is not unconnected with the same cause, because it is mainly through scientific training that we have come to see the need for sound method in all our undertakings if high efficiency is to be attained. No true educationist can thus afford to let his eye wander from science, whether he is designing curricula, planning legislation, or seeking to improve administration.

The teacher has also much food for reflection in this connection. The last decade of the century saw great changes of opinion in regard to him and his work. With every additional enhancement attached to the value set upon education his status has improved; and with every step towards the nationalisation of his subject the more willing has the State been to view him as an honoured and trusted servant. All credit to him that he has come to recognise the

justice of the State's return demand that he shall adopt his profession in the proper spirit, and shall seriously set himself to be trained for his life-work. The old delusion that he who has learned can teach has been an unconscionable time in dying, but there is not much life in it now. Even the most conservative bodies have during recent years changed their front in regard to the matter, and surely the last word on the subject has been said at the Conference which assembled at Cambridge in December last. The Conference was fully representative of the Universities, of the various teachers' associations, and even of unprofessional educationists; and the first words of the chairman, Sir Oliver Lodge, in summing up the points upon which all the members were agreed, were: *Training is necessary for teachers of all grades.* In the last three words, "of all grades," there is much virtue. No stopping short at the elementary teacher, on whom for many years training has been obligatory; nor at the secondary teachers, whom even the English Head Masters' Association would now like to see moderately trained; but embracing all, even those who have to teach within the walls of a college.

Another point which has to be noticed in regard to teachers has a closer bearing upon our present meeting. This is, the fast growing conviction that the teacher who wishes to be effective in his daily professional work must keep up a living interest in his subject, and according to his opportunities must be a contributor to its advancement. The latter obligation, of course, increases in weight with the rise in grade of the teacher; in the case of a university professor the will and the capability to do research work should be considered indispensable, and should be valued at least as highly as the power to interest and to teach. One of the great functions of a University, everywhere recognised of late years, even in the most utilitarian centres of population, is to enlarge the boundaries of knowledge: in other words, every University worthy of the name should have in essence the same aim as this association, viz., the advancement of science. With the removal of all school work from certain of our colleges, and with the consequently increased aid available for higher education and the increased interest taken by the public in their endowment, we may surely hope with confidence that an aim of this kind will be kept steadily in view in the future. In regard to certain recent appointments, I am greatly pleased to say that the Council of the South African College entirely agreed with me on this point: the fruits of the Council's action should be seen in Section B at future gatherings like the present. The plea of want of originality which has sometimes been set up in England, as an excuse for no research output, shows a complete misunderstanding of the nature of the demand made. There are whole fields of needful work which requires no originality of mind for its accomplishment. With merely a fair knowledge of his subject, with a fair knowledge of languages, and with a reasonably trained intelligence, any man can do such work, for example, as I have tried to do in a communication to another section of this association. And yet the importance of work of this kind, bibliographical, is undeniable:

without it real progress is well-nigh impossible. Then there is the large field of effort to which bibliographical work leads up, viz., the historical field. With every year added to the life of science, the more imperative it becomes to attend to its history, so as to foster width of view and to keep before investigators the more fruitful trends of thought. Again, there is the preparation of specialists' text-books and books of reference for the use of advanced students, who need guidance and encouragement to become themselves investigators. The demand for this is clamant in English-speaking lands, as every teacher knows. More might easily be instanced: it is not the small size of the vineyard that is to be blamed: "the labourers are few."

Let us all hope that one outcome of this gathering will be a large increase of workers in South Africa, single-minded workers, content even to plod if they may only prepare the way for greater men to follow.

### 38.—THE PUBLIC LIBRARY SYSTEMS OF GREAT BRITAIN, AMERICA, AND SOUTH AFRICA.

BY BERTRAM L. DYER, LIBRARIAN OF KIMBERLEY, AND FORMERLY OF THE KENSINGTON AND TOYNBEE LIBRARIES.

"What a sad want I am in of libraries, of books to gather facts from. Why is there not a Majesty's Library in every county town? There is a Majesty's gaol and a gallows in every one!"

When we realise that these words were those of Thomas Carlyle only some seventy years since, we are vividly reminded how young and how recent a thing is the Public Library as known in Great Britain, in America, and in South Africa.

Yet who, in these early days of the Twentieth Century, would venture to suggest that Public Libraries do not come within the category of things which it is absolutely necessary that a wise Government should cause to be provided by the collective action of the community it rules over.

It has been claimed that the modern Public Library movement was started in America—that England caught the infection, and that thence it extended over the world.

But the claim is very largely a fallacious one, and however much may have been done by America to extend and develop the work of libraries, there is no gainsaying the fact that there exist at this moment on the Continent of Europe Public Libraries, maintained by public funds and by private benefactions, which have been in existence for centuries; while with one exception in London, one in Manchester, and possibly two in America, there exist no modern English Public Libraries that can claim an antiquity of more than one hundred years.

America claims that when New Hampshire placed on its Statute Book in 1849 a provision for the upkeep of its Public Libraries by a tax, that this was the first occasion of the provision of a Public Library from public funds, other than the establishment of Royal Libraries. But so far back as 1818 Cape Colony had established a Public Library, whose funds were derived from a tax upon its then principal product. In the words of the Proclamation, the design of the Government of the Cape was "to lay the foundation of a system which shall place the means of knowledge within the reach of the youth of this remote corner of the globe, and bring within their reach what the most eloquent of ancient writers has considered to be one of the first blessings of life—Home Education."

This public-spirited ordinance, made as it was in the first quarter of the Nineteenth Century, is the first instance of a public provision for libraries in any English-speaking dominion, and entitles Cape Colony to rank as the pioneer of State-supported Public Libraries.

though the wine tax was diverted to the general funds of the Colony in 1825, and a pittance of £300 per annum paid out of it for a couple of years, until in 1827 the tax was repealed, and the library handed over to a Committee, thus ceasing in effect to be a Public Library under State control. Not till 1862 did the Government of the Cape again contribute toward the upkeep of the Library, but in that year the sum of £600 was granted toward its maintenance, and grants have been made ever since.

By private benefactions it is true that there were older English Public Libraries—that of London, for instance, being founded in the fifteenth century, but this had disappeared entirely by the seventeenth. The Library of New York in America, too, had been founded in the last year of the seventeenth century, but it may be said to have remained utterly neglected, till in 1754 the efforts of Benjamin Franklin (commenced in 1731) founded the Library Society of Philadelphia, to be, as he says in his "Autobiography," "The mother of all the North American Subscription Libraries now so numerous. These libraries have improved the general conversation of Americans, have made the common tradesmen and farmers as intelligent as most gentlemen in other countries," and, we may add, have continued to prosper to the present day, receiving large benefactions by gift and by bequest, and frequently being largely subsidised by public funds.

In 1761, within seven years of Franklin's foundation of the Philadelphia Institution, Cape Town and London both received donations of books, which, curiously enough, were both handed over to churches until the community should claim them for a Public Library. It is interesting to note that Cape Town had claimed its Dessenian books from the hands of the Consistory of the Dutch Reformed Church, and had housed them in its Public Library in the first quarter of the nineteenth century, but it was almost at the end of the last quarter of that century that Shoreditch claimed from the Churchwardens of St. Leonard its heritage of the Dawson books. Cape Town had her Library six years before the Corporation of London took steps to refound her Guildhall Library, and nearly half a century before the sister city of Westminster permitted the Trustees of the Tenison Trust to sell by public auction the books that Archbishop had willed to his foundation at St. Martin's.

In England there were Subscription Libraries in the eighteenth century, which, if we may believe the evidence of Sheridan, circulated little but fiction, but they do not appear to have flourished. Some of them have been able to continue to modern days without absorption into more useful institutions, but the majority have disappeared. The same is true of Scotland and of Ireland, and few of the older libraries there have developed on the lines that similar institutions have done in America. Birmingham affords, however, a most successful instance of the growth of a Subscription Library, and its development alongside and within near reach of one of the most successful of the Free Town Libraries established under the Ewart Acts.

Early Subscription Libraries there were in Cape Colony beside that of Cape Town taken over from the State about 1830, for Swellendam established her Library in 1838, George hers in 1840, and Graaff-Reinet hers in 1847. There is an amusing passage in a letter of Molteno's which he addressed to his mother in London in 1844, which forms a curious commentary on the Library facilities enjoyed by the Metropolis of England and that of Cape Colony. He writes:

"I much wish you could obtain a proper account of the Cape, perhaps you may be able to get the loan of a recent work, there are several. If you were so fortunate as we are at the Cape in having a Public Library of 30,000 volumes to resort to, you would experience no difficulty in this respect."

To realise the utter dearth of Public Libraries in Great Britain in 1849 one has only to turn to Hansard and read the speeches of Mr. Ewart and Mr. Bretherton in the House of Commons, both in moving for the appointment of the Select Committee and in introducing the first Library Bill. The Report of the Select Committee is one of the most remarkable documents in the history of popular education, and the following passage deserves quotation. Dealing with libraries on the Continent of Europe it states: "It may generally be stated that admission is granted unreservedly to the poor as to the rich, to the foreigner as to the native. We have only one library equally accessible in Great Britain with these numerous libraries abroad. Nor is this contrast displayed by the European Continent alone. Our younger brethren—the people of the United States of America—have already anticipated us in the formation of libraries . . . entirely open to the public. Your Committee feel convinced that the people of a country like our own, abounding in capital, in energy, and in an honest desire not only to initiate but to imitate, whatsoever is good or useful, will not linger long behind the people of other countries in the acquisition of such valuable institutions as freely accessible libraries. Our present inferior position is unworthy of the power, the liberality, and the literature of the country."

By one year New Hampshire had ante-dated this measure, and Massachusetts followed with her Library Law in 1851, but it should be stated that Peterborough, in New Hampshire, had established her Library out of public funds in 1833, and Warrington, in England, hers in 1848, though such expenditures were perhaps hardly lawful till the Library Acts were passed.

In 1862 Cape Colony, as we have seen, again provided public funds for her Cape Town Library, and on the 21st August, 1874, an Ordinance was published, giving the regulations under which public funds would be granted to libraries throughout the Colony on the £ for £ principle.

Natal in 1851 founded her first Library, and at the present time has a somewhat similar system of grants in aid, a system which has very recently been adopted by the Governments of the Orange River and Transvaal Colonies.

Having thus attempted a summary of the history of the library movements in the three countries, I now proceed to a comparison of the general conditions at present existing, prefacing these, however, with the explanation that my acquaintance with the systems is of such a character that it is impossible for me to speak authoritatively upon them, and that my conclusions have been arrived at tentatively after a residence of little more than two years in South Africa, nearly the whole of which time has been passed in one town.

The Library Law of Great Britain as amended to date leaves it optional to the inhabitants of an area to tax themselves to the extent of one penny in the pound on the annual valuation, and this sum may not be exceeded without the special sanction of Parliament. Very few towns have sought and obtained such permission, though there is a very general feeling that the limited rate is inadequate.

Once adopted the Acts cannot be dropped again easily. The control is vested in the Local Authority, who generally appoint a Committee from among themselves, and from that class of educated residents which is not always attracted to municipal work. The Committees vary largely in number, from about ten to nearly fifty, and apart from financial supervision, the Local Authority rarely interferes with the Committee in its work. There is no grant from central Government Funds, and no Government inspection or supervision.

In America the Library Committee is nominated by the government, or elected by the subscribers. It usually consists of from three to nine members. It is state-controlled, there is government inspection, and frequently a State Library Commission attempts to ensure the adoption of systematic work on general lines of unity. Frequently the Education Board of a State controls its libraries.

In South Africa the subscribers elect the Committee, usually twelve in number, and there are two trustees representing the Municipality and the Government, and there is a Government inspection of accounts.

There are 403 libraries in the United Kingdom deriving their income from library rates. Of these 336 are in England, 15 in Wales, 15 in Ireland, and 37 in Scotland. There are about 100 subscription or semi-public libraries in addition.

In the United States of America there are upwards of 1,200 tax-supported libraries, and at least 1,000 libraries supported in other ways. The Northern States have far more and far better libraries than the Southern, and the distribution of libraries is far from uniform. Massachusetts leads the way, and this State alone has in her Public Libraries  $3\frac{1}{2}$  millions of books, as against  $5\frac{1}{2}$  millions in all the Public Libraries of England.

Cape Colony in 1900 had nine large libraries in her principal towns receiving special grants, and about 100 receiving £ for £ grants. The total number of books in all the libraries in the Colony is not half a million. Natal has 20 libraries—or rather she had, because one was unfortunately destroyed in the late war—and

at this date it is impossible to present any data as to the state of the libraries of the Orange River and Transvaal Colonies.

Private donations have not very largely helped the library movement in England. The reverse is the case in Scotland, and of course American citizens have nobly helped the cause in their own country. In Massachusetts, which can claim indeed to be "the banner State," no less than 120 libraries have been built at a cost of  $1\frac{1}{2}$  millions of money, and if we exclude the recent gifts of Mr. Carnegie, there do not appear to have been 50 libraries given to the whole of Great Britain. Gifts of libraries to South Africa are hard to find, though the noble bequests and gifts of the Savage family to Port Elizabeth deserve special mention. But apart from the Dessinian bequest to Cape Town, the gifts of Sir George Grey and of Mr. Hiddlingh, also to Cape Town, and the MacFarlane gift of £500 to Kimberley, I am unable to trace any others.

The Cape Government has made special grants in aid of the building of libraries, but in Great Britain the usual way that a library has been built has been by mortgaging the future income of the rate. America helps in many ways. One State gives grants, another gives books, yet another hands over part of the State lands, and in addition to the money raised by local taxation, many States hand over other revenues to the Library Boards. One hands over the Dog-Tax, another the fines from the Magistrates' Courts, and one State in particular pays a sum for each book circulated.

To compare the amount of money devoted to libraries in the three countries is very difficult owing to the different methods of rating, taxing, and granting adopted. But I would point out that while Birmingham, a city of 429,000 inhabitants, devotes only £14,437 to libraries, Boston, with 448,000 inhabitants, devotes £51,562. Taking other towns of equal size on the two sides of the herring pond, Newcastle-on-Tyne devotes only £4,331, while Newark and Minneapolis devote £8,043 and £14,321. Aberdeen spends only £2,248. Oldham £2,155, Blackburn £1,959, Bolton £1,908, Sunderland £1,031; yet Newhaven, with its smaller population, spends £3,712. The total library expenditure of Great Britain is less than £210,000, while the two cities of Boston and Chicago alone spend half of that sum between them.

Turning to South Africa, the total amount paid out of the general revenues of Cape Colony in 1899-1900 was £9,000 as against £10,752 in the previous year. The total number of persons subscribing was 9,438, and the total number of books only 421,731. Natal only paid from her revenues £1,952, and the total number of volumes in the Colony was under 50,000, while she had but 3,073 subscribers.

Recently I tried to test the work that we were doing in Kimberley by comparing it with that which was being done by equal-sized Public Libraries at Home. There are, I found, twenty libraries in Great Britain of between 25,000 and 40,000 volumes, and they are variously situated. They vary from Norwich, founded in 1850, and St. Helens, founded in 1869, to Carlisle, founded in 1890,

and Shoreditch, founded in its present form in 1891. The populations vary from 365,000 at Belfast, and 122,000 at Shoreditch, to 30,000 at Richmond, and 39,000 at Carlisle, and the annual expenditure varies from £4,280 at Belfast and £3,580 at Hampstead, to £800 at Darlington and £870 at Yarmouth; but taking the average I found that a population of 84,000 persons had a library income of £1,812, a stock of 28,000 books, and issued 73 per cent. of fiction out of a total annual issue of 136,000 books. Kimberley, with its population of 15,000 whites, spent last year upwards of £2,000 on its library, possessed 26,000 books, and issued 75 per cent. of fiction out of a total of 40,000. If you reduce these figures to average per unit of the population you find that Kimberley spent 2s. 11d. per head on the library, while the average for the twenty Home libraries was only 5d. per head. And if we look at other towns, we find Birmingham does not spend 9d. per head, while Aberdeen spends less than 6d.; yet if we turn to America we find Boston spending 3s. per head and other towns considerably more.

But what Boston spends annually on her library per head of her population is found by the Government, and we must compare her 3s. with only 7.2d. of our 2s. 11d. in Kimberley, for the Cape Government only gives us 5.6d. and our Municipality 1.6d.; our local subscribers paying in themselves for the privilege of using the library a sum equal to 12.7d. per head of the whole population of the town, while our donations from the De Beers Company have equalled 4d. per head of the population in every recent year.

Equally remarkable is the number of books read at Kimberley if you consider that we have no leisured community there, but that we are mostly people engaged in hard and laborious work all day, for last year we issued 2 $\frac{2}{3}$  books to each unit of our population as compared with only 1 $\frac{1}{2}$  books per head in the average of the twenty towns with libraries on the whole rather larger than ours.

With regard to taxation, American and South African Libraries are practically exempt, but most British libraries pay both local and Imperial taxes.

Art Galleries and Museums are frequently attached to libraries in England. In America there is a great dearth of Museums and of Art Galleries. Cape Colony possesses only five and Natal two, and it would be well if the recognition by Great Britain of the educational function of Library Boards by giving them the charge of Museums and Art Galleries were copied in South Africa.

Turning to the libraries themselves, we find that in America the Reference Departments are small; the books are nearly all available for home reading. In England the reverse is the case, the Reference being frequently larger than the Lending Department. In South Africa we frequently adopt a happy medium by putting our books in the Reference section and permitting their issue on special signature form. The use made of the Reference Departments is difficult to shew in comparison, because it is most unusual in South Africa to keep records of consultations in this department, but it is

noteworthy that Manchester, which has only a third of the population of Chicago, has three times as many readers in its Reference Library.

The popular tendency to be impressed by big figures such as this does not always tend to the realisation of the highest ideals in library work, and if England's highest record is in her Reference work, America achieves a wonderful record by her home circulation of books. And we must never forget in comparing British libraries and American libraries with those of South Africa that both the former reckon their Reference issues with their Lending in working out the average of fiction read, and that library statistics, unless subjected to the most careful test, are very often misleading. In one State of America, where the amount of the Government grant is based on the issue, the result has been to excite a feverish desire to increase the issue alike by Library Boards and staffs, and while the Library Board would only buy such books as were good "circulators," without consideration whether such books were of real value to the community, the library staff insisted on every unfortunate user of that library taking out each time he or she visited it two books—one of which might not be fiction—despite reluctance or protest, and all because "of the statistics."

Where the American Library system does score, and score well, is by the admirable system of delivery stations that exists in nearly every town of any size, which literally serve to bring books to the doors of the people. By the provision of books for schools, fire-stations, lighthouses, factories, etc., and by her prompt recall of books, America leads the way in library work. She gives special facilities to her school teachers to borrow books in big batches to illustrate lectures and courses of study, and she turns her every teacher into a library evangel, and her every schoolroom into a preparation ground of future library readers.

School libraries in connection with the larger Public Libraries are not uncommon in Great Britain. Nottingham early led the way, Carlisle followed, and few or no libraries have not a juvenile section or a children's room. Out here they are hardly known, but the magnificent provision which the Cape Education Department makes for the encouragement of libraries in its schools is such as to relieve the Library Board of much responsibility, though school libraries would be helped and not hindered by closer relationship with the Public Libraries.

Public reading-rooms which provide current newspapers are the exception rather than the rule in the States, Chicago, however, being a splendid exception. In Great Britain they prove one of the most popular departments of the library's work, though one hears an occasional grumble at the expense or at the betting-man, who rushes in for the latest telegrams. In South Africa the public reading-room frequently contains only the day or week old paper that has already done duty in the subscribers' rooms, but a more liberal spirit now actuates many of the larger libraries.

Few English libraries permit chess or draughts on the premises, and I am only acquainted with one that has a smoking-room. On the contrary, most American libraries encourage the use of the library as a quiet club, though the large existence of the woman librarian serves to banish St. Nicotine. South Africa is free and easy in its ways, and there is a delightful homeliness and liveableness about many of its libraries which few in America and hardly any in Great Britain can equal.

The use of the library rooms by the literary clubs and societies of the towns is not so much encouraged in England as it is in America, and it has been practically unknown in South Africa, but a change seems imminent, and Johannesburg promises to lead the way in a welcome innovation, which will make the library the home of all literary movements in its vicinity. Other towns are wondering if they also cannot make the dry bones of the valley living forces to the young people of the town.

Lectures in libraries are far more common in Great Britain than they are in America, and while not unknown in South Africa are worthy of much more extended trial.

Great Britain has in many of her towns a magnificent system of branches which are as characteristic as are the American delivery stations. Out here branches are practically unknown, each little village preferring independence to relationship with the one large library of a district, but I believe that the solution of the South African Library problem will very largely be found in the linking up of the smaller libraries with the larger, and an efficient system of interchange. The only effective branch library that I know in South Africa is that of Kenilworth attached to Kimberley, and this is maintained by the liberality of De Beers Company for its employes, and constitutes at this moment the only Public Library in South Africa, which in all departments is free and open to all the residents of the place which contains it.

For readers in scattered country districts, America in her library system especially caters. Great Britain more frequently ignores this most necessary work, and in our South African library system one of the best features is the way that the Governmental grant aids to establish and fosters the growth of libraries in places that would be deemed too petty to have a library in Great Britain or America, unless in England they possessed a Verney as landowner, in Scotland were the birthplace of a celebrity, or in America were chosen as recipient of a millionaire's gift. These libraries, frequently poor, generally isolated, only need linking up with the larger libraries to produce a library system that is unequalled.

Rapidly glancing at the library economy of the three countries, we find that the hours of opening and closing are much the same. English and South African libraries are usually closed on far more days than is customary in America, but this is mainly because they are understaffed. America has practically abolished the frequently unnecessary inconvenience of closing the library three or four weeks in the year for stocktaking. When libraries are properly staffed

they can with advantage keep open nearly every day in the year, and can shut in sections for cleaning and stocktaking. Closing libraries on public holidays is utterly indefensible, especially if they open on Sundays. Yet libraries that open on Sundays should be careful to see that no member of the staff works seven days a week, even at the cost of closing a half-day in the week altogether as some American libraries do, or of closing the Lending Department for the same time as most English and American libraries do.

Of course in South Africa our Lending Departments are entirely limited to subscribers, while in America and Great Britain they are as free as our public rooms. Ratepayers or burgesses there use the library entirely without charge, and frequently without any further formality than the signature of a guarantee to return books. Other residents have to get a ratepayer's or burgess's undertaking to be responsible for books lent. In but few places may an applicant leave a money guarantee; but, speaking from the library point of view, the signature system leads to endless trouble, and the system of deposit as usually adopted in South Africa works infinitely better, though it might in certain cases deter the poorest from borrowing books.

Age limits are practically unknown in South Africa, and they are higher in Great Britain than in the States. The Library of Congress admits readers at 16, the Corporation of London at 18, the British Museum at 21.

Less than a score of English libraries allow the public access to the library shelves, and most of these only with an elaborate system of wicket gates and barriers, while the majority of libraries use an indicator, usually of the kind invented by Mr. Cotgreave, of West Ham. In America these are little used; two libraries at least in South Africa use them. For the issue of fiction an indicator offers undoubted advantages, as this invention throws upon the seeker after the latest or the most sensational novel the labour of hunting for its number over a small space, instead of sending members of the library staff all over the building. I think that rapidity of issue on busy nights is much helped by their use, and to turn an unordered crowd of men and women loose among a collection of novels, as we frequently do in South Africa, does not help toward good reading, and only serves to hinder the library staff.

No method of library issue that has ever been invented equals that of the Cotgreave indicator either in simplicity, rapidity, or accuracy, as English experience has proved, but failing these the best system is undoubtedly that of card-charging; and few or no American or British libraries use the out-of-date ledger system used so often in South Africa.

Classification of books on the shelves according to subject is the ideal of every library, but in spite of many elaborate systems, few libraries in Great Britain have yet accepted any uniform plan. Two systems divide America, but under each the libraries are closely and minutely classified to the great advantage of those who use them. Except at Cape Town, Bulawayo, and the Reference Department

of Kimberley. I am unaware of any attempt at scientific classification in South Africa, yet it is little to be doubted that the Dewey or Decimal system is making headway both in England and in America, and will be also adopted in South Africa, thus enabling all libraries to adopt a uniform system.

As for time allowed for reading, two weeks seems universal, but fines for exceeding this period vary tremendously. Manchester has never imposed a fine; California, on the contrary, makes it a misdemeanour to detain a library book thirty days after you have been asked to return it. In South Africa we fear to impose fines for fear that we shall lose subscriptions.

As to library staffs, America boasts of an elaborate system for training librarians in their profession, but, practically, it is seldom available for any but assistant librarians, because librarianships are there, like most civil appointments, party spoil to be divided among the faithful henchmen of the victors at each election. In England librarianships are seldom the prey of political party; they are usually advertised, and there is often keen competition, in which not infrequently the trained and capable assistant from a library is defeated by the local candidate, who has earned a pension in some other sphere of life, and whom it is desired to give a supposedly easy billet to. But the idea of a librarian as something more than a mere keeper of books is abroad in the land, and the Library Association has instituted a professional examination, though at present its diploma is held by no librarian. Both in England and in America libraries have found it advantageous that assistants shall have had at least some bibliographical training, and that experienced assistants are the best methods of making the contents of the library readily accessible.

Out here librarianship has grown up with the library movement, and against the one librarian of Cape Colony who seems to have remained in his profession to develop in a most remarkable manner the Cape Town Library—need I say that I refer to Mr. Jardine—all else that I can learn of previous generations of library assistants is that they deserted their libraries—the one to win the name and fame of being the greatest of South African poets—while the other became your first Premier. But Pringle and Molteno were hardly trained librarians, and the apparent lack of that native product in South Africa has led to the appointment of those who have gained some experience in the libraries of the Home Country.

In America many more women are employed in libraries than in Great Britain, and the great superiority of the children's libraries in the States is doubtless due to the fact that they are in the charge of women. Of course the woman librarian is paid a less salary than the man, but it must never be forgotten that a staff which does not look to its profession as other than a temporary occupation, and is frequently changing, is not the best staff. Girls in a library may be younger and fresher than boys—and possibly of a better type than many of the boys that our small incomes compel us to employ—but however much they may be desirable from the æsthetic point

of view, youth and freshness are not the best aids when you seek some out of the way book or desire information on some by-path of knowledge.

English librarians work longer hours than American, but reliable statistics as to South African Libraries are not available. Many libraries here are apparently open 11 hours a day for six days a week, and some hours on Sunday, too, with only a staff of one, but so many of the South African libraries are open without any staff at all, except the kindly person who drops in once a week to set things straight, that without a personal acquaintance with each it were hard to draw any conclusions. The same remark would apply to the salaries paid in South Africa to librarians, for the average amount paid in salaries in the country is not £20 per annum. Outside of Cape Town, Port Elizabeth, Kimberley, Durban, Pietermaritzburg, and Johannesburg the total salaries paid in any one library do not exceed £250 per annum. Manchester pays in salaries nearly £9,000 a year, while Chicago pays £27,000, and the higher efficiency of the American library is very largely due to the fact that she can not only attract the best men to her service, but that she can afford to pay them the salary which will be high enough to prevent commercial life offering higher inducements.

Of Associations of Library workers, America had the first, which is of course numerically the largest. England has her own Association, a very strong Association of Assistants, and an independent Society of Public Librarians. England publishes three Library Journals, and so does America. Though debarred from all active part in the English Association, even of voting at the Council Elections—South Africa has no Library Association, no Library Journal—but I trust that each year opportunity will be found at the meetings of this Association to have a meeting of those interested in the library development of this Sub-Continent. America believes in conferences of co-workers in libraries, and so does England, and if the isolation of the South African libraries makes it impossible in any other way I trust the annual meetings of this Society may serve to draw together the workers in the different library fields for exchange of ideas and comparison of work.

Before attempting to sum up the conclusions of this hastily compiled and rambling paper I would desire to acknowledge the great assistance that I have obtained from the writings of Mr. Andrew Keogh, now of Yale, and formerly of Newcastle Libraries. From an essay of Mr. Miller, of Bulawayo, on South African Libraries, published in "The Library Assistant," I have also gained much information, while the works of Thomas Greenwood, Edward Edwards, W. I. Fletcher, and the Hon. P. M. Laurence have been laid under contribution in my endeavour to place reliable information before you.

As the result of our examination of the three systems we may conclude that the English librarian regards his library rather as the storehouse of knowledge than as its distributing centre. The

traditions of being a Keeper of Books are to a large extent still with him, and the impossibility of ever lending a book which characterises the older libraries—such as the Bodleian—is a custom which it is hard to break away from; and it is this tradition and this custom which makes the Reference Library so large in England. In England the desire of the librarian is to have the best books on every subject, and to keep them if possible on the library premises. In America the ideal seems to be to obtain the most popular books, those that will circulate best, and many an up-to-date committee will buy no book, keep no book, that is not a good circulator. More often than not the American Library is a club for the reading of new books—frequently only of new novels. I fear that the same charge may with truth be levied against many a South African Library, and though Kimberley does its share in this respect, it is not quite so bad as Sir Frederick Young pictured it, for we certainly do not issue a greater percentage of fiction than any other library; indeed, it would be hard for any library to beat Johnny Gilpin's Edmonton in this respect, which issues 98 per cent., according to the last available figures. But though English libraries do circulate much fiction, there is yet set before the libraries of the Old Country a very lofty ideal, and they do attempt a great deal of educational work.

This is true of but few of the American libraries, for the majority of these are run on business lines, and on these lines alone. There is less formality about the better libraries of the States—less red tape—and in all there is an attempt on the part of the library to reach down to the special needs of the people. The library seeks to be the centre of literary feeling in the town—it seeks to attract the children, and to lead them into the use of better books.

The South African libraries can with advantage adopt the best points of both systems. We should attract the public, and not attempt to discipline it; but yet we should endeavour to lead the younger generation toward the right use of the best books.

The American and the British peoples are not exactly alike, and our South African public probably differs from both. For example, American productive scholarship is far less than British, while South African can hardly be said to have come into existence. The sale of popular books is tremendous in America, less in Great Britain, and small indeed in South Africa.

American libraries seek rather to be recreative than educational, British libraries to be educational rather than recreative—South African are at present more recreative than educational—yet the enormous impulse that was given and is given to American progress by her school system has been largely helped by her library system. The first stride that America made towards "licking creation" was when Franklin founded the Philadelphia Library, and her present liberal policy in all educational matters is only its continuance.

The modern American cheerfully taxes himself for his libraries, but he does not largely use any but the Lending Departments. Yet he frequently endows his library—and certainly his women-folk and his boys and girls make good use of the library. The Englishman

spends far less on his library, but he takes from it and reads in it vast quantities of history and travel and technology, while his women-folk read the novels. The South African uses the library as a sort of occasional club; he takes his recreative reading from it, and some other more solid mental pabulum, but he is usually a very busy man, whose ideas are focussed rather round his bank book than his library books, and he more often than not is quite content to leave all serious reading and recreative study to that middle or old age which he devoutly hopes shall find him dwelling out of Africa. Yet his women-folk use the library a great deal, and his boys and girls are being accustomed in the schools to a right appreciation of books, and as they grow up they ought not to be permitted to grow out of the custom and the use of them. Home education is the watch-word of the Public Library in South Africa; and we must so develop the library system of the country that not one child who has passed through its schools may remain out of touch with a literary storehouse.

And this is the *crux* of the situation here. Our libraries so far as Lending Departments go are essentially subscription libraries and nothing more. I do not desire to belittle the fact that we have reading rooms free and open to all, but the duty of the Legislature with regard to the library movement will not have ceased until Lending Libraries, free and without charge, are established. In America we find such developments of the work, and if the Legislatures of South Africa, by increased aids, were to add Public Lending Departments, the Subscription Departments would only temporarily suffer, and in the long run would benefit. At Kimberley we have tried the experiment of throwing all our rooms open to the subscriber personally for the low annual charge of £1, with one book at a time for home reading, while families of three have full personal privileges for £2 annually, and families of five for £3 annually. This we have been enabled to do, not by increased Government grants, but because of the great help that we receive from De Beers Company (renting as it does its village library from us at an annual cost of £200 and giving us in addition £250 per annum), and because in past years not only have the library buildings been built and furnished and stocked, but an endowment fund of upwards of £6,000 accumulated to add to our one little legacy. But in Kimberley, with all our resources, we have reached the *ultima thule* as regards lowering of subscriptions unless the Government is prepared to further recognise the work that we are attempting. The result has been a gratifying increase of revenue from subscriptions, while the increased use of all departments is remarkable. As always the reading room is free to all to consult or read books in, and it may be said that there are no persons resident in Kimberley to whom the subscription of £1 a year is a real bar to home reading; yet American experience has shewn rapid increases in the use made of libraries when even smaller barriers have been removed, and I am confident that when the time arrives when the libraries of South Africa are placed more in public control, and larger sums of public money are paid toward their support, their usefulness will be enormously increased. Something

about the fact and the sense of ownership in a public institution, free and untrammelled, provided by the collective action of the community for all classes of the community, and not for sections of it, kept up mainly by the people's taxes, and under popular government, makes the average person accept and use opportunities far more largely than any privileges which may be offered to him under the guise of a Subscription Library. Compare the marked difference that is made of a popularly controlled library like that of Boston with that which is made of a library under a select Board like the Astor, and one is forced to the conclusion that the people like best to use that which is their own.

A library which exists as a close corporation, no matter how much it is aided by Government or Municipality, is only a stepping-stone to that Public Library which is an essential part of the educational system of the state, and which is always a standing witness of the self-reliance and public spirit of the community that maintains and uses it.

The one expenditure, and the only expenditure of a Government which is returned an hundred-fold to the country governed is its expenditure in educational work; and if South Africa is to go ahead and make strides like the States have done, it will only be by a return to the principle laid down in 1818, by which "Home Education" is placed in the forefront of the schemes of the Government.

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### 39.—ITERATION AS A FACTOR IN LANGUAGE.

By WM. RITCHIE, M.A.

The question has often been discussed whether the study of Language can be classified as a science, and, as usually is the case in such discussions, the question itself turns upon a point of language—the meaning of the word science. We are apt to regard science as limited to what may be called the exact sciences—such as Chemistry or Physics—in which our knowledge of certain facts and principles leads to the further knowledge of what will at any time happen when these facts and principles are applied. The chemist knows for a certainty that when he combines two or more substances the same definite result will follow. His scientific knowledge enables him to predict future results. In like manner the astronomer can predict the future position of the various heavenly bodies from the definite facts and laws he has ascertained in regard to them. To limit the name science however to such sciences would be to exclude all the Natural Sciences. The Zoologist carefully collects his facts regarding all the phenomena of life upon the earth;—he traces the course of development from the most rudimentary forms to the most highly organized, and forms his theories regarding the principles at work which have led to the results we see. But no zoologist would venture to dogmatise on what will be the result of any cross-breeding of animals or to lay down infallible rules for farmers on this subject. So too the Botanist collects his facts and forms his theories and reduces his knowledge to order. He takes the evidence afforded him by the forms of plant life which the rocks have preserved and ransacks the world for new specimens, and on these facts he inevitably founds theories of the causes of development at work in this sphere. But he will refuse to prophesy with certainty on the results of cross fertilization, and will not make his fortune by the creation of new varieties of attractive blossoms. He will know far more than the market gardener of the principles at work, but his knowledge will not enable him to dogmatise as to the future. Now, the study of Language stands in many ways just in the same position as Zoology and Botany. It has its array of ordered facts of observation, partly fossilized in the remains of languages which have ceased to exist as living organisms in the earth, partly living in the languages still existing and spoken by the various races of mankind. These phenomena it proceeds to study and reduce to order, and there generally emerges a classification of languages into genus and species based as in all the natural sciences on definite affinities and resemblances. In the process of classification there inevitably appear certain principles or laws—some coextensive with language itself, some more limited in range. Yet we can never reach such exactness of knowledge as will enable us to prophesy with certainty. Take one problem to exemplify our meaning. Given the fact that two languages meet on the same soil, what will be the result? Will the one destroy

the other? If so, which will be the stronger? Will the one which prevails be unaffected by the other, or, if affected, how far will the intermingling go? This is not an imaginary case, as any one will know, but one which is occurring now, and has occurred on countless occasions in the endless past. For example, what will be the issue as between Dutch and English in our own country? We may be inclined to venture on prophecy there, and yet how far from sure we can be. Given a different result to the events of the past few years and the problem might have taken quite a new complexion. And even as it is, who shall fix a date for amalgamation or absorption or modification? We know the principles, and we see them in constant operation, but we cannot be precise as to their effects. The fact is that all our calculations are vitiated by an unknown X, whenever living organisms are subjects of our investigation. The Zoologist may lay down with the most rigid accuracy the characteristics of the animal "sheep," but the knowledge will not help him much in the determination of the character of an individual sheep. The Political Economist may say that men buy in the cheapest and sell in the dearest market, but a boycott may be established in defiance of the principle. The same limitation will be found to exist in all the sciences which deal with life in any of its phases. We have to content ourselves with collected facts and with general principles which explain these facts, but we cannot dogmatise about any future combination, the problem being generally too complex to admit of accurate prognostication. The study of Language is more than all other sciences subject to this limitation, as it deals with the very implement of all thought, the sphere in which the influence of individuality is specially prominent.

We find continually in language two opposing forces at work—a centrifugal and a centripetal force—a force which tends to uniformity and a force which tends to eccentricity. We wish at present to look at one phase of the force which tends to uniformity—the various phenomena of iteration which form a very striking feature in all languages. We mean by Iteration the tendency to repeat entirely or partially sounds already uttered. It will be noted that Iteration, if it prevailed completely, would be the negation of language as articulate speech, and would reduce language to the more or less monotonous repetitions of similar sounds which we find characteristic of the lower animals. Hence it is not an unfair inference to suppose that we come near to the first beginnings of speech when we deal with the phenomena of Iteration. We are led to the same inference when we see that Iteration is specially characteristic of children or of the races of mankind who come nearest children in intellectual development. As the physiologist may see an epitome of the development of the human race in the development of the individual man from the embryo to the fully formed adult, so we may see in some measure the development of language in the gradual acquisition of the powers of language from infancy onwards. If we follow this thought we shall see Iteration beginning as something which we might call almost mechanical or purely animal, and

gradually being employed as a device in language which may be put to the most diverse uses which the more complex needs of growing intelligence suggest. What lies at the bottom of the impulse to iteration may be somewhat uncertain, but we cannot be far wrong in assuming that there is something pleasurable in the mere repetition along the same line of a current of nerve impulse, and that up to a certain extent the doing of a thing once or the uttering of a thing once tends to produce a repetition of the action or the utterance. We see this clearly enough when the repetition has proceeded far enough to produce a habit of action or speech, and the greater includes the less, so that we must conclude that each individual action or utterance has a tendency to repeat itself.

The relations of Speech to what may be called in the widest sense Music have never been fully investigated, and the subject, dealing as it does with the very roots of sensation and thought, is a very difficult one, but we may see a parallel between speech and music in their respective developments which bear upon the question of Iteration. Savage music is chiefly Iteration—the drum is the favourite instrument—and as men advance in intellect so their music advances in variety, and Iteration becomes less marked. But as in all language, however highly developed, Iteration is still a perceptible factor, so in all music, however complex, Iteration has its distinctive place. Let us now see how Iteration appears in the actual phenomena of language.

I. We have Iteration in its most obvious form where whole sentences, phrases, or words are repeated. As we shall see presently, this form of Iteration is most commonly found in the mouths of children, or of races intellectually childish; but we should not lose sight of the fact that the child in this respect is father to the man, and that the tendency is seen at all ages of life, and in the cultured as well as in the uncultured. We need only point to the phenomena of catch phrases, vulgar street cries, to show how strong the tendency is in the less cultured; but we must also note that even in the most intellectual there is a tendency to adopt and to use continually certain favourite phrases or turns of speech which become more or less an individual note of personality. Note, too, the tendency in public speakers to repeat a phrase or sentence. Probably there are few of my hearers who could not name some acquaintance who has the Iterative habit either in sentence, phrase, or word.

II. A second form of Iteration, which is also very widespread in Language, occurs when the monotony of simple repetition is crossed, and the effect made perhaps thereby more pleasant by a little variety. To apply the analogy we have drawn between music and language, the monotony of the drum is relieved by the addition of the fife. It is worth while under this second head to subdivide the various forms of variety, as they have in many cases important effects in the general structure of languages.

1. We may note the common phenomenon of general Iteration combined with simple vowel change. Such combinations as jingle-jangle, ding-dong, would be familiar illustrations of a phenomenon

common in most languages. The constructive uses which such changes may be put to in language we shall note presently.

2. We may note also the frequent occurrence of Iteration which affects only parts of words. Under this head we might again subdivide into Iteration at the beginning, at the middle, at the end of words, as well as the combination of these partial iterations with vowel changes. A further subdivision might be made according as the iteration is of the vowel or consonant part of a word, but we need not elaborate overmuch. The phenomena of such partial iterations are most commonly found at the beginnings or ends of words, and are perhaps more conspicuously seen when they affect consonants.

- Ex. :—a. Momordi, *pepuli*.  
 b. Aliguguli (from the singular *alguli*).  
 c. *ἐπὶ ἄνω* (*épew*), &c., &c.

III. Thirdly, we may note what may be called *veiled* Iteration—*i.e.*, cases where there is fair reason to conclude that certain phenomena of language are due to an original Iteration which is no longer actually visible, but which has left traces of its effects on the structure of words. Here, of course, we are on much more unsafe ground, and in many cases cannot be sure whether the phenomena are due to the residue effects of iteration or to some other cause of phonetic change. For example, when we find in Latin an iterated or reduplicated form like *peperi*, and find that a compound of this verb *repperi* has dropped the visible doubling but has retained a double p, it is obviously fair to conclude that we have in this consonant doubling the veiled form of iteration. But when we find that certain verbs in Latin form perfect stems by a vowel lengthening, and that in Greek a similar lengthening is accompanied by Iteration, it is not so certain a conclusion that we have in this lengthening a veiled reduplication, for we find other indications that such a lengthening may be due to other phonetic causes. Still, however uncertain we may be as regards particular cases, there can be no doubt that we have here a *vera causa* and that if we had the means of tracing the history of dropped iterations we should see their effects in many of the phenomena of phonetic change.

We may now look at the various ways in which iterative forms are used in language, and we shall see that Iteration plays an important part, whether language be in its most primitive or in its most highly developed forms. We shall look at the various uses of Iteration in what may be regarded as a kind of chronological order, though it must be remembered that the earliest uses survive to a certain extent and are to be seen side by side with the later. We should naturally expect that this would be the case, for man, however highly developed, is still an animal, and Iteration may be said to be based on an impulse common to all animal nature. "Naturam expellas furca tamen usque recurret"—and "Scratch the Russian and you will find the Tartar"—are proverbial expressions which find their exemplification in language continually. The (H)arry who

catches up some music-hall phrase and uses it *ad nauseam* is only obeying a very primitive instinct of speech.

1. First, we may place what may be called the Infantile or Primitive form of Iteration, of which words like *mama*, *papa*, are standing instances. Every one is aware of how large a part Iteration plays in the language of the nursery. No doubt a good deal of this is traditional, and is learnt from elders who pass on the primitive language of their own infancy to the next generation, and rejoice greatly when their youthful offspring first gives utterance to the *ma-ma*, *pa-pa*, *ta-ta*, which herald the introduction into the complex paths of human speech. But apart from what is the result of mere imitation there is no doubt, whether it is the speech of children or the speech of savage races that we study, that here Iteration plays a very important part.

2. Closely connected with this first form of Iteration, and hardly to be separated from it, is the combination of Onomatopœia with Iteration. Here also the language of the nursery gives numerous examples. The impulse to imitation, which lies at the very foundation of language and its acquisition, is obviously essentially connected with Iteration. Sounds, and still more words, are not acquired by one attempt, so that imitation and iteration go naturally hand in hand. Moreover, the sounds which are imitated in onomatopœia are the distinctive sounds which are constantly repeated, and iteration in connection with them is therefore natural and obvious. We need not give more than an instance or two of such words; *Puff-puff*, *tick-tick*, or with slight change of vowel or consonant, *bow-wow*, *tick-tack*.

3. A third division may be made—though it is closely connected with the other two—where Iteration is used for Comic or Contemptuous expression. The real point of distinction here is that there enters in a new factor, which we may call Sub-Consciousness on the part of the speaker. Note that the history of language is practically the history of unconscious change and development. Language, except in the rarest instances, such as the deliberate inventions of new words for new inventions, is anonymous, and we cannot point to the honoured names of the fathers of speech. But in spite of this we must admit a kind of sub-conscious effort on the part of each individual which culminates in the unconscious progress of a language in one direction or another. When an urchin in the street repeats an opprobrious epithet directed at some object of his spleen, the repetition may in one sense be as unconscious as the repetition of the nursery, but there is at the same time what we may call a sub-consciousness that the repetition makes the epithet far more effective. The number of such comic or contemptuous iterations is very great—examples like *tittle-tattle*, *skimble-skamble*, *hoity-toity*, etc., may suffice. It may be noted that they are generally accompanied by some change of consonant or vowel.

4. We may next notice a very common type of Iteration, which is best specified as the Iteration of Emphasis. In one sense this heaving might be used to characterise all iteration, but it is convenient to limit it to the cases where emphasis is the predominant

feature. Nothing is more common in conversational speech of all races, high or low, than this emphatic repetition of words and phrases. Yes, Yes, has more force than a simple affirmative. No, No, does not conform to the rule that two negatives make an affirmative. Far, far away means more than far away. Note that the iteration may be confined to a part of the word as in many intensive forms such as *παμφαίρω*, or in the very common childish habit of lengthening a vowel sound—a habit which is an exceedingly common one with adults as well as children in our Colony—a bi-i-ig man being a much taller personage than merely a big man. We see the same kind of iteration for the sake of emphasis continually in public speaking, sometimes prefaced with: "I repeat, gentlemen," frequently done without preface and unconsciously.

5. Our next division we shall call Grammatical Iteration. It covers a very wide field of language phenomena, and may be regarded simply as the application of emphasis to various linguistic purposes, the result often being that the iteration becomes quite veiled by phonetic change until it requires investigation before it can be recognised. If we asked *à priori* to what purposes iteration would naturally be put, as language developed, it would not require much thought to select such grammatical phenomena as the comparison of adjectives and the formation of plural forms in nouns as being obvious spheres in which Iteration might play a part, and the history of language would confirm this selection. But the use of iteration goes far beyond this, and we find it used for nearly all the purposes which we class under the head of grammar. Languages in their unconscious growth do not respect logical principles as Volapuk may do, and a device which has been employed in one connection is not ear-marked and set aside for that purpose, but is widened in its applications to embrace many other purposes by that curious gradual process of metaphor and analogy which is characteristic of all linguistic growth. Let us briefly note some of the uses in grammar in which Iteration is obviously employed.

(a) The Comparison of Adjectives and Adverbs.—In expressions like far, far away, a long, long time, we have the beginnings of the usage, and in many uncivilised languages this is a regular grammatical usage—*e.g.*, in Accadian Gal-Gal—very great.

(b) The Plural of Nouns.—Man + man may easily connote the plural idea, and we find this device frequently used in languages of the less civilised types, *e.g.*, the plural tu-tu in the Bushman dialect—houses. The iteration may be only partial as in the Tepeguana instances quoted by Sayce, ali—child, a-ali—children, ogga—father, o-ogga—fathers, etc. Perhaps we may see in the common nursery expressions "to play at house-house, at shop-shop," the same phenomenon.

Whether in any of the suffixes employed in most languages for the purpose of expressing the plural there lies hidden the residue of primeval iteration is a problem which admits of no solution.

(c) Verb forms expressing continuous, repeated, or intensified action.—Such synthetic forms have been mostly superseded in

civilised languages by analytic expressions, but they are common in less civilised languages and in older forms of civilised speech. Thus the continuous or intensified form of the Dayak *kaka*, to laugh, is *kaká-kaka*; the Brazillian *acem*—I go out, has the frequentative form *ace-acem*. It is tempting to believe that in the common frequentative or intensive suffixes in Latin and other language (*e.g.*, *rapio*, *rpto*, *raptito*, *capio*, *capto*, *captito*), we may have a relic of the same usage.

(*d*) Very closely allied to this continuous or intensive use of Iteration is the employment of it in the formation of the present forms of verbs in which the idea of continuous action is often present. This use is very characteristic of the Indo-European languages, and is seen conspicuously in Sanskrit and Greek. The Iteration is only partial, and assumes the form we are familiar with under the name of reduplication—*dadami*, *δίδωμι*, etc.

(*e*) Reduplication is also extensively used as a grammatical device for expressing tenses of the verb other than the present, more especially the perfect and to a less extent the aorist *δεδωκα*, *dedi*, *did*—*ἔγγαγον*, etc., etc., will serve as instances of a class of phenomena which is very familiar in the Indo-European languages.

There can be little doubt that phonetic change has in a great many instances veiled original iteration in the verb forms till it can no longer be recognised. Some have fancied that the augment which is characteristic of past tenses in such languages as Sanskrit, Armenian, and Greek may be a veiled form of iteration, and if we could believe that a device first used in verbs beginning with a vowel afterwards became general the theory might be a plausible one, but the evidence is altogether wanting.

(*f*) Another use to which Iteration may be put in the grammatical structure of languages is seen very well exemplified in Latin, where indefinite pronouns or pronominal adverbs are commonly formed by reduplication; thus, *quis-quis*—whoever; *quo-quo*—whithersoever; *quot-quot*—how many soever, etc.

(*g*) The most striking of all the various grammatical uses to which Iteration may be put is afforded by the languages which have been called variously Alliteral, Euphonic, Prenx-Pronominal, and which are more or less familiar to us as the languages spoken by the Bantu tribes in the Southern half of Africa. In the case of these languages the whole sentence structure is dominated by an elaborate form of Iteration, by which the governing noun of the sentence draws all the other words of the sentence into phonetic harmony with it, the various words being altered in their prefixes to suit the noun. In Kaffir, "with the exception of a change of termination in the ablative case of the noun and five changes of which the verb is susceptible in its principle tenses, the whole business of declension, conjugation, etc., is carried on by prefixes and by the changes which take place in the initial letters or syllables of words subject to grammatical government. By this principle of the language there occurs the repetition of the same letter or letters in the commencement of several words in the same sentence," *e.g.*, *Izono zam zininzi*

zihleli entliziweni zide zingabi nakuxolelwa, (My sins are many; they possess the heart until there is no forgiveness) where Izono is the governing noun.

6. The last use of Iteration which we shall call attention to may be called the Literary use. We have spoken previously of a sort of sub-consciousness in the use of this device. In this last use of it, though a great deal is no doubt still half instinctive or semi-conscious, a good deal is also conscious and intentional. We may divide the literary use of Iteration into four sub-divisions:—

1. *Alliteration*, where a succession of words occur beginning with the same letter. We have already seen what is practically the same phenomenon in the primitive and grammatical uses of iteration, but the literary usage of the device is worthy of a separate heading. It is practically universal, and exemplifies very clearly the fundamental nature of this iterative tendency in language. The quack who advertises "Pink pills for pale people" is as much under the universal influence as the exquisite poet who writes:—

And on a sudden, lo! the level lake  
And the long glories of the winter moon.

It is a difficult question to settle how much of the alliteration which constantly occurs in all writings, ancient as well as modern, is conscious, how much semi-conscious, how much altogether unconscious; but we know at any rate that a good deal of it is entirely conscious and intentional. We find it used in poetry continually from the earliest to the latest times, and it appears in some poets and in some periods of poetry as one of the most characteristic features. It is one of the notes of Latin poetry, and in such writers as Plautus and Lucretius it affects the whole writing. But as we have seen in the case of the Bantu languages that Iteration may become the basis of all grammatical construction, so we find in the case of Scandinavian and Old English poetry that Iteration may become the basis of the structure of verse. In these cases the whole verse-structure becomes a combined system of accents and alliteration. "Each full (long verse) has at least four accented syllables, and is divided into two half (short) verses, divided by a pause, and bound together by alliteration; two accented syllables in the first half verse and one in the second beginning with any vowels (generally different vowels) or the same consonant. There is often only one alliterative letter in the first half verse." The words: "Raw flesh ravens got to rive" would give a fair idea of the kind of verse.

2. *Assonance*.—Here the resemblance is not in the initial part of the words but rather in the general structure of the words. The name assonance is sometimes used in a special sense for the resemblance between words in their vowel sounds apart from any resemblance in consonants. In this sense we may note its use in literature in the older forms of Spanish poetry where assonance served the same purpose as rhyme at the ends of lines, the words at the end of consecutive lines having the same vowel sounds though not resembling each other in their consonants.

In a looser sense the word assonance is used for any resemblance of sound, and might be applied to the phrases, so common in most languages, which resemble the primitive skimble-skamble type—such as “fair and square,” “right and tight,” “under and over.”

In this connection it might be noted how different in some respects modern literary taste is from ancient—at least so far as prose is concerned. In modern prose, at all events, the repetition of a word or phrase, unless a decent distance separates it from its first occurrence, is a thing carefully avoided, and we resort to all manner of synonyms to avoid what seems to us an inelegance. It is a curious instance of the negative pole in thought—the repulsion from what we feel to be an attraction. We exalt the negative of a natural impulse into a virtue of style—just as we exalt the repression of natural emotion into a virtue of social conduct. In more simple and less conscious literary expression there is no such avoidance of repetition. Homer repeats perpetually, and we find in a writer like Lucretius a word like *ratio* occurring almost half a dozen times in as many lines, and that too in different shades of meaning. We probably err from over-fastidiousness, and often reject the best word for some inferior synonym for fear of repeating ourselves.

3. *Punning*.—It may seem somewhat of a sacrilege to put this under the Literary division of Iteration, but it is so closely allied to the phenomena of Alliteration, Assonance, and Rhyme that it seems best to classify it along with them. In Punning we have, along with the resemblance of sound, the incongruity of meaning and the comic association of incompatible ideas which add attractiveness to this freak of language: “The parson told the sexton and the sexton tolled the bell.” All of us are to a certain extent susceptible to the funny side of punning, but we all know how inexpressibly wearisome is the incorrigible punster and how easy it is for the habit of punning to become a disease of language. That very fact illustrates how deep-seated is this Iterative tendency in language, and illustrates also the repulsion to the natural tendency which we have spoken of already.

4. *Rhyme*.—Here the resemblance is in the end syllables of words—confined generally to the last syllable, but often extended to the syllable or syllables preceding the last. As a standing feature of verse-construction rhyme is comparatively a modern expedient, but, no doubt, in its beginning it goes very much farther back. We find a very considerable number of rhymed couplets in Homer, as well as lines where the first half ends with a word rhyming with the last word of the second half, but probably these rhymes are accidental or unconscious, and chiefly owing to the inflexional endings being similar. Still, we may suppose that the pleasing jingle of such lines caught gradually the ears of writers, and when Latin poetry ceased to follow the elaborate prosody it had borrowed from Greek and relapsed under the influence of the barbarian invasions into the accentual form of rhythm which was its more natural expression, the fondness for all forms of assonance and alliteration which is so characteristic of Latin poetry, probably found its natural vent in the gradual development of rhyme. This form of verse-ending became

common in the Romance languages, appears in the Germanic languages somewhere about the ninth century, and from thence onwards becomes characteristic of a very great proportion of the poetic compositions of all civilized languages. The innumerable ways in which rhyme has been used in the varied construction of verse-forms need not detain us. They are simply illustrations of the pleasure which human nature finds in diversity combined with similarity which we have seen already exemplified in other forms of Iteration.

We have called attention before to the parallelism which exists in many directions between Music and Speech, more particularly between music and emotional speech or poetry. In both of these one cannot fail to see how great a part Iteration plays. All folk-music is iterative or melodic in its structure, and so is all folk-poetry. Music may develop, as it has done, into wondrous variety, which plays round its central theme till resemblance seems lost in diversity. Poetry may make its rhythms and verse construction elaborate, may seek to avoid the mere jingle which appeals to the uneducated ear, but both alike must not go too far if they are not to cease to exist. The force which tends to Iteration is a fundamental one, and until human beings cease to respond to the measured beat of military music we must regard the influence of Iteration in all its wonderfully diversified forms as something rooted in the very essence of human nature.

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#### 40.—CAPE-DUTCH.

By W. S. LOGEMAN, L.H.C., B.A.

It may perhaps seem to be no more than a disguised tone of the *captatio benevolentiae*, or of the usual pseudo-modesty of authors, if I start by saying that I do not imagine that I can offer in the following paper the fruit of much original research, or any brilliant contribution to the knowledge of my subject. No, this disclaimer states a sober fact, and my only motive for coming before you, with a few observations on Cape-Dutch, is that I believe the subject interesting, and that I think that a discussion may lead others to take it up, and to pursue it, as it fully deserves.

It may be as well to state at the outset that I intend to treat my subject exclusively from a philological point of view: I will not discuss the political question of equal rights for the Dutch and the English Languages; I shall not touch upon the question of the greater or less æsthetic value of Cape-Dutch; I shall not ask whether it is an advantage or a disadvantage for any people to have two languages spoken more or less correctly by most, and a third (a miserable mixture of both) by the less educated of its members.

My purpose is—starting from the undoubted fact that the language exists, that it is spoken daily by thousands and thousands of people, and is dear to their hearts,—to combat some prejudices against it, to defend it against some silly accusations levelled at it, generally by those who know very little or nothing of or about it, or who know it only in its most debased form, the form which it assumes in the mouths of kitchenmaid or Cape-boy, and..... I am sorry to have to add, in the mouths of many who consider themselves educated, and who say they love their language, but give the lie to their assertion by uttering the most awful mixture of Dutch and English that intellectual laziness, or shallowness of mind has ever produced.

If I speak of Cape-Dutch, I do not allude to such talk as I myself, *e.g.*, have heard of a young lady, who at a flower show called the attention of her friend to a bunch of flowers which she had sent in, and communicated this interesting fact with the words:

"Kijk toch, Minnie, that's one of the pieces wat ik het gebreng."  
Or of another who stated that she did not much care for the photograph of a group in which her likeness was not sufficiently distinct, by declaring:

"Ik is baai disgusted, jij kan mij features niet sien nie."

Such *olla podrida* may be good enough for a servant girl who declares that:

"De master z'n tie is in de drawer where de missus z'n gloves in lê,"  
but is unworthy of any one who does not wish to stand on a similar low level.

The Cape-Dutch I do allude to is the language as spoken by the intelligent farmer, the language written in what literature it possesses, in *e.g.* the periodical "Ons Klijntji," in the little poems of

Reitz or Melt Brink, in the stories and more ambitious larger works of the Rev. S. J. du Toit, etc., and such as that gentleman uses in his proposed translation of the Bible, etc. etc.

I shall try to show that this language fully deserves study from a linguistic, scientific point of view, and defend it against some remarks I have heard or read in its dispraise. I intend to discuss its origin, stating what has so far been written about it, and point out some of the problems still to be solved concerning it.

This latter: the formulating of what is still to be done will, I hope, "set others going," and I hold that he who—prevented by whatever circumstances—cannot himself work at a problem, contributes to its solution by removing obstacles which might prevent others from paying attention to it.

If, in the course of my remarks, I repeat some text-book truths which are the common property of all who have ever occupied themselves with scientific study of any language, my excuse must be that in this paper I am probably addressing but few who are already students of linguistic problems, and chiefly those whom I should like to encourage toward becoming so, by showing them that what they thought was beneath their notice possesses unsuspected value and interests worthy of their best efforts.

One of the commonest remarks made again and again by those who for the moment I will call the detractors of Cape-Dutch is: "Cape-Dutch is no language, it is a mere patois!"

It would—so it seems to me—be perfectly fair to ask those who utter this platitude with all the weight of ignorance and self-satisfaction of imagined superiority, that they should define the terms they so glibly use, and tell us what they mean by a "language" and a "mere patois," and that they who so confidently deny the right of Cape-Dutch to be classed with the one, and condemn it to rank with the other, should clearly state where they draw the line, and the reasons why they assign to Cape-Dutch a place among the goats rather than among the sheep.

No linguist has as yet been able to draw that line, no one has as yet told us where a "language" begins and a "patois" ends.

If the aggregate of articulate utterances which serve a community of people to tell one another of their thoughts, their hopes, their beliefs, their best and noblest feelings, their wishes, their loves, their purest affections, to express their joys and their griefs, their hatred and their admiration, if that is a "language," if no one hesitates to speak of the "language" of the Kaffir, the Papuan, or the inhabitant of the Tierra del Fuego, just as well as of the language of England, of France or of Germany, what reasonable argument can possibly be adduced for denying this title to Cape-Dutch?

Or is it because in so very many respects it still very closely resembles the tongue of Holland, the language spoken by most, if not all, the first settlers, the language of which the very name of "Cape-Dutch" reminds us? I hope to show a little later on that Cape-Dutch has developed—allow me to call it for the moment "regularly," "correctly," "legitimately,"—along a way of its own, a

way quite as interesting and as worthy of study, as any other tongue, but surely resemblance to a language which boasts of a noble literature cannot be justly imputed to any speech as a blemish!

Or is it the very fact that Holland *e.g.* possesses such a literature, which gives it a right to which Cape-Dutch cannot lay claim?

He who will maintain this should first make quite sure that his assumption is correct, and that Cape-Dutch does really not possess any Literature.

No one will think of denying that to speak in the same breath of the Literatures of say Holland or England, and of Cape-Dutch is a case of *parva cum magnis*, of *minima cum maximis componere*. Nevertheless, even my own very incomplete collection of publications in Cape-Dutch occupies quite a respectable space on my bookshelves, and contains poems of the true ring, of warmth and wit, tales and a novel of no inconsiderable literary value. Though small, there *is* a beginning, and no one would have denied the title of "language" to English or French at the time when what was written in them for literary purposes was as insignificant in quantity. Nay, once more: the name of "language" is constantly and unhesitatingly applied to dialects in which nothing has as yet been written. And had mankind no "language" before the art of writing was invented?

To say "Cape-Dutch is no language" is a mere senseless playing with words. It sounds like sense, but can only serve to display the speaker's ignorance.

"Ah well," says another detractor, "Cape-Dutch may serve for uneducated people to talk to one another, but it "has no Grammar!"

Once more we may ask for some greater clearness, more definiteness in the accusation. Pray, what is meant by this pompous imputation, which sounds so fearful, but contains so little?

Let us for a moment consider what IS grammar. What, *e.g.*, does a missionary do when he comes for the first time into contact with some tribe, amongst whom the art of writing is as yet unknown, and whom he is the first to visit? His position is a very difficult one, but, by pointing out things, he soon learns their names, he watches what the people say when they act and evidently encourage one another, or even him, to act, he picks up an exclamation, soon a phrase here, and a word there, and ere long he acquires greater and greater facility in not only understanding what the natives mean, but also in imparting his own thoughts to them. His superior intellect and knowledge prompts him to utter thoughts quite new to them, and he eventually becomes a leader, a master instead of a pupil: he uses the words they already possessed in gradually changing sense, he extends their application, he modifies, or gives them additional meanings.

This he does not do at random, but—having become familiar, as far as possible, with their vocabulary and their mode of thinking, having, more or less consciously, observed the changes of names of things and actions, made by the natives in their words, or in their order of these words, to express various relations of number, tense, mood, etc., etc.,—he introduces, may be, new names for new things.

but treats these new words in conformity with the rules he has abstracted from the mass of concrete examples, with which he had at first to struggle as with a *rudis indigestaque moles*. He arranges and classifies, and—when for the sake of others, who are to come after him, and who may wish to acquire the “patois” or “dialect” or “language,” he writes down in some regular order and grouping the facts he has observed, the similarities, the analogies, the rules which the speakers unconsciously follow, then he “writes a Grammar” of that language. He *writes it down* for the first time, but... he does not *make* it, he does not *create* something which did not exist before.

In judging of his work we must then never forget two things:

1st. His Grammar is only “correct,” in just as great a degree as he has correctly observed, and correctly stated the facts of the language, as it is spoken by the natives; and we may in passing observe that he never goes in for the absurd statement which we can so frequently hear from thoughtless schoolmasters of our days: “that people generally SAY this, but that really it OUGHT TO BE that.” Whatever the comparatively intellectually advanced, the older, the wiser people, the leaders among them, habitually say, that “is correct”; whatever goes against usage is “incorrect” and if the facts of the language were found to differ from the facts or rules stated in his book, then that would be a great pity for... the book.

The facts which he classifies and states in some rational or convenient order and arrangement, these are the authority, and he is merely codifying, and has to obey them. In other words, the language is the master, and the grammar-book has to obey: the language rules the grammar and the grammar does not rule the language.

The rule is correct if it is in conformity with usage of the language, and no native will tell his boy or girl that any expression is “correct” because it is so stated in Mr. X’s book, or “incorrect” because Mr. X. stated in his book that he, Mr. X., considered some other—may-be older—way of expressing the same thought preferable. The native leaves such folly to the modern, wiser, “better-informed,” schoolmaster.

2ndly. The facts and the usage, the regularity of treating similar words in a similar manner under similar circumstances, all these constitute the grammar and all these existed long ere any one ever thought of classifying, arranging and grouping them for facility of imparting a knowledge of them, or out of a spirit of philosophical inquiry. In other words the language “HAS A GRAMMAR,” quite independently of the question whether any one has ever attempted to state that Grammar in writing.

We must now ask once more: What does our detractor mean when he says: ‘Cape Dutch has no grammar’?”

If he means what he really has no right to call so, that the facts of Cape-Dutch have not yet been codified, that no grammar-BOOK has as yet been written, even then his statement is quite incorrect, but... even if it were correct, it would be merely a statement that something which would be very interesting to do, has not yet been

done, and surely, that fact, if it were a fact, which it is not, could not be a reason for despising the language!

Or, can he possibly wish to assert that those who speak Cape-Dutch use each independently of the other all various and constantly varying forms, constructions, orders or combinations of sounds, which the one at the one moment employs for some idea, and the same man at another moment, or another man at the same moment, uses for quite another notion? Surely, the idea is inconceivable: no collection of sounds so used could possibly serve for intercommunication of thought, and no one, be he ever so anxious to sneer at any "patois" or "dialect" or "language," could possibly make such an assertion.

I think we may dismiss the statement that "Cape-Dutch has no Grammar," without further discussion or comment.

A third accusation or observation made frequently against Cape-Dutch refers to many of its constructions and to the forms of very many of its words, and originates with the Hollander who, fresh from Europe, and—perhaps pardonably—misled by the name of the language, *Cape-Dutch*, i.e., Kaapsch HOLLANDSCH, commences by measuring what he hears and reads by the standard of what is "correct" and elegant or refined in his own country and language. He hears forms like *ons is*, instead of *wij zijn*, *vark* for *varken*, *koe* for *ko*, etc., etc., and these grate on his ear; to him they seem here, what in Holland they would undoubtedly be, gross mistakes, silly or vulgar abbreviations or unnecessary lengthenings.

Generally,—before having inquired in how far his ideas are well founded—he will express his opinion freely, in the presence of others who cannot judge for themselves, and the man in the street may well be pardoned if he repeats what he has heard asserted by one who "ought to know": that Cape-Dutch is full of mistakes, that it is silly and "very ungrammatical."

As soon however as any one realises what we discussed a little while ago, that in language certainly, if anywhere, "whatever is, is right," that there is no "yes, but it OUGHT to be" against the decrees of the *usus tyrannus*, he will become less confident in his assertions as to the inferiority of Cape-Dutch, and, if he will inquire seriously, so as to gain the right of giving an opinion on the matter at all, he will soon find that the history of his own, or of almost any other, language will supply him with parallel instances of similar developments, and that what seems to him at first silly or incorrect, is generally but an instance of what may sound uncouth to HIM, but has happened again and again in words of his own speech, words which do not sound to him silly or incorrect for absolutely no other reason than that he is accustomed to them, and ignorant of their history and older form.

It is of course impossible to prove this here in a complete collection of all instances that might be adduced, and it would even be impracticable to take a LARGE number of these cases.

Let us just go over the few incidentally given above: the Acc. *ons* for the Nom. *wij*; the shortening of *varken* to *vark*, and the

lengthening of *koe* to *kœi*, and then discuss the form *Afrikaander* which not very long ago some ignorant anonymus made the text of a long sermon in the "Cape Times" about the stupidity of Cape-Dutch.

It undoubtedly does sound bad to a Hollander when for the first time he hears *ons wil* for *wij willen*, and, when he has told his English friend that the Cape-Dutch form is just as bad as if in English one were to say *us will*, they both raise their eyes in pious and pitying horror and give thanks that they "are not like these."

But..... ARE they not? In English the Nom. of the personal pron. of the 2d. pers. Plural was *ye*, and the Acc. was *you*. The man who for the first time said *you have*, for *ye have*, made absolutely the same mistake as he would make who now said *us have* for *we have*.

But the *usus tyrannus* has accustomed us to *you have*, and therefore it now IS correct and now SOUNDS correct. The only marvel is that there is not some wiseacre who says: "Yes, we all say *you*, but it ought to be *ye*," and then proposes henceforth to reintroduce the older form.

It will be unnecessary, I trust, to point out that I am not trying to argue that the Englishman ought henceforth also to use *us* as nomin., because he says *you*, but I do maintain that if *you* for *ye* is not incorrect now, and is not a sign of intellectual inferiority, merely because usage has established it, the same reason ought to be admitted as sufficient to justify *ons* for *wij* in Cape-Dutch.

And the Dutchman? true, he does not use the ACCUSATIVE for the nom., but..... instead of that nomin. HE uses..... the GENITIVE, or—if he prefers to call it so—the nominative feminine of the possessive adj. pron. ! Unblushingly he will assure the Afrikaander (with the D.!) : "*ziet u, ons is verkeerd, u moest wij zeggen.*" This little word *u*, which he considers, and which of course now IS, the correct translation for the acc. form *you*, is nothing but the remnant of the fuller polite form of address : "*uwe edelheid*," i.e. *your grace*, which still lives in the obsolescent *uwee*, and which can be perfectly matched by the Italian *Lei*.

And have not both the Englishman and the Dutchman muddled up their Datives and Accusatives, when they began to say *him* or *hem*, really or originally the *dative* forms (of German *ihm*) instead of *hine* or *hen*, which forms still live in several of the dialects?

Does all this mean that *u* or *him* or *hem* is "wrong," and that henceforth e.g. the Englishman, proud of his newly acquired historical information ought to say : "*I see'n* . . . Of course not ! But, once more ! if *him* is now right, though once it was wrong, and if not even the schoolmaster pretends that it "ought to be" *u*, why then object to another, perfectly parallel transition in usage in another language, merely because in OURS that particular change has not taken place ?

We need not, and cannot, discuss with equal fulness of detail the other forms we quoted, but it will be sufficient to remind him who objects to the omission of the last syllable in *varken*, which omission is due to an unconscious, in this case mistaken, feeling that the ter-

mination is the sign of the plural, like it really is e.g. *boeken, stoelen*, etc., etc.,... to remind him, I say, of the fact that in Holland-Dutch exactly the same has happened, e.g. in *raaf* (cf. Engl. *raven*), in *baak* (by the side of which even in Dutch itself we still find the form *baken*, and which is the same word as the Engl. *beacon*); that in Engl. the word *pea* is a remnant of what was once, in the singular, "(a) *peas*," similarly mistaken for a plural, whilst in its turn this very form "*a peas*" was an abbreviation of *peasen*, from which the termination *en* was omitted for the mistaken reason in a time when this *en* was also in English still a common termination of plural-forms. And *cherry* instead of (a) *cherries*, with which we compare the French word *cérise*, from which it comes; the well-known "*heathen chinee*" for *chinese*, the *shay* in which we find the remains of the French *chaise*, are not these and many others parallel?

Next to the singular *koe*, Dutch has the plural *koeien*. If Cape-Dutch has from this plural formed a new singular *koei* by merely omitting the *en*, has not the Dutch of Holland done exactly the same in *vlooi* from *vlooten*, the "regular" plural of *vloot*?

And now that *D* in the word *Afrikaander*, which the "Cape Times" correspondent maintained was a sign of ignorance or of I-do-not-know-what in the poor benighted man who thus dares to call what "ought to be" *Afrikaan* or *Afrikaner*, do we not find exactly the same sound inserted between the *n* and the *r* in English *thunDer*, once *thunor*; in Dutch *donDer*, with both of which we can still compare the German *Donner*; in the Dutch *minder*, the comparative of *min*; in the French *Vendredi*, the *Veneris dies*; in the future of *venir*, *je vien Draï*; in the Greek *ἀνέρε* Genitive of *ἀνρ*, etc., etc.

Or is the same thing in Classic Greek a sign of wisdom and elegance, in English, Dutch, or French not worth talking about, and in Cape-Dutch wrong, stupid or silly?

To whom would in this case these adjectives best apply? I should like to ask.

I trust I have in the foregoing remarks given a sufficient reply to some if not all of the main objections made frequently against Cape-Dutch as a "language." I repeat that I purposely omit all discussion as to the desirability of maintaining it as a second (or first) official language of this country. The most violent opponent of its rights or of its claims to continued existence may grant all that is here maintained: my object is to show that Cape-Dutch need not be looked down upon, that it fully deserves a study of its History.

It is to this, or rather to the first question which presents itself to the student in connection with it, that I now wish to call your attention for a little while. What—it has naturally been asked,—is the origin of Cape Dutch; whence this development so very different from that of the language which has been its main source?

The first, as far as I know, who made any serious attempt at answering this question was Dr. W. J. Viljoen, now my esteemed colleague, Prof. of Mod. Langs. at Victoria College, Stellenbosch.

As subject for his "Thesis" or Essay, required by the University of Strassburg from Candidates for the Degree of D. Lit., he chose:

Beiträge zur Geschichte der Cap-Holländischen Sprache, which were published in 1896.

In 1899 Mr. D. C. Hesseling published:

Het Afrikaansch, Bijdrage tot de Geschiedenis der Nederlandsche Taal in Zuid-Afrika. (Leiden, E. J. Brill).

And in 1901 there appeared in Göttingen:

Die Sprache der Buren.—Einleitung, Sprachlehre und Sprachproben, von Dr. Heinrich Meyer. (Fr. Wunder).

The second of these works is by far the most important from our point of view.

Dr. Viljoen commences with a very short note on such points of the political History of the white population of this country as he considers of importance for his subject: the settlement of the Dutch, the arrival of the Huguenots, and how these were absorbed by the Dutch, and lost their language. (12 pages.)

A note on the ethnology of the native tribes and on the intercourse between these and the white population occupies the next 4 pages.

Pp. 17-32 contain all that Dr. Viljoen tells us on the question that is at the moment occupying our attention.

This is in its turn followed by a short note on—almost a bibliography of—what has been published since 1844 in Cape-Dutch, whilst pp. 39-58 contain an excellent first scientific attempt at describing the phonology of the language, as it now exists. This part again, however valuable in itself, is for our present purpose of no importance.

The 16 pages which contain Dr. V.'s views on the History of the language are inevitably not to be compared in thoroughness with the work of Dr. Hesseling, whose whole book of 156 pages is devoted to that subject.

As far as I am aware, Dr. H.'s results stand uncontradicted: the great advance he has made on the work of his predecessor was due to a more extensive study of original documents than Dr. V. had found time for, and to his consequent discovery and demonstration of the great influence which Malayo-Portuguese has exerted on the development of Cape-Dutch, an influence the existence of which had been entirely overlooked by Dr. V.

I intend in what follows to give a VERY short summary of Dr. H.'s work and will here only quote one remark made by Dr. Meyer, in the third little work mentioned above. Dr. Meyer avowedly bases what he says concerning the History of Cape-Dutch upon the two books of Viljoen and Hesseling, and accepts the latter's views. What he gives is—once more we can say "of course" since the little book contains Grammar and Reading texts, and only discusses the History of the language incidentally and in the short space of some 7 pages: a mere sketch. He makes however special mention of one fact which neither Dr. V., nor Dr. H. seem to have taken much notice of, and which—just as the immigration of the Huguenots explains the

frequent occurrence of family names amongst the Boers which are clearly of FRENCH origin (*e.g.*: Viljoen, Joubert, Marais, du Toit, Beranger, Rousseau, de Villiers, Ciliers, du Plessis, Cronjé, etc., etc.) points at the reason for the many names which are as evidently German (Schreiner, Reitz, Steyn, Krüger, Hofmeyr, etc.).

Quoting from Theal's History (Vol. II) he gives the latter's statistics of immigrants, classified according to nationalities as follows:

	Ger.	Dutch.	French.	Others.	Total.
1657-1675 ... ..	6	32	1	7	46
1675-1700 ... ..	32	48	50(?)	24	154
1700-1725 ... ..	83	97	10	73	263
1725-1750 ... ..	172	69	1	30	272
1750-1775 ... ..	254	82	2	62	400
1775-1795 ... ..	198	106	8	79	391
	745	434	72(?)	275	

Amongst these "others" there are 34 Swiss.

Dr. M. then points out that whilst undoubtedly the Hollanders formed the decided majority of the settlers,—[about 2/3 of the white population.]—the other 1/3 consisted of GERMANS and FRENCH, with a very various but unimportant admixture of comparatively few others of all kinds of nationalities.

All these elements soon disappeared, and even the Germans who immigrated in such considerable numbers were not able to maintain their separate national character. Two things are to be remembered in this connection: First: that most of these immigrants, generally soldiers or sailors, had led before landing here a life of adventure and varied experiences: having been in contact with all kinds of peoples and in all kinds of places. Secondly: that most of these representatives of the various nationalities were men, whilst the female population was recruited almost exclusively from Holland or France. The men of other nations therefore had either to die without offspring or marry those women, and be absorbed by *their* nationality.

The white population then at first spoke Dutch, which they had as it were "brought with them" or acquired soon after landing.

It is Dr. Hesselings's merit to have explained how it was that their language has developed so rapidly and in so peculiar a fashion to what we now find it.

I have no doubt that Prof. Viljoen was right when he asserted that practically all the peculiarities of Cape-Dutch existed before the people came into closer contact with the English, and that the influence of the English language has been considerably over-estimated. But Dr. H.'s work shows, and he proves by quotations from his sources and authorities, that this statement does scarcely go far enough and that

(a) Cape-Dutch, even that of two centuries ago, differed largely from all Dutch dialects, and

(b) that, though there are exceptions to the rule that the language of a colony is more conservative than that of the mother-country, it would be very difficult, if not impossible, to find any example of so great a deviation from the mother-tongue, **WITHOUT THE INFLUENCE OF A FOREIGN LANGUAGE.**

In the case of Cape-Dutch, he says, it is absolutely impossible to think of spontaneous development of Dutch idiom when we see that as early as 1739, *i.e.* only 87 years after the founding of the colony, a language is used in written documents that differs widely from anything known in any dialect of Holland. In the manifestoes, issued by a Sergeant Barbier, leader of rebellion against the Gouverneur, we already notice *ous* for *wij*, the loss of the termination of the infinitives of the verb, and many of these simplifications in the conjugations which now sound so strange to a Dutchman's ear.

Cape-Dutch is a "Mischsprache," "Mengeltaal," a "Mixed Language," and if we wish to understand its history and development, we must first of all try to find out of what people the Hollanders in South Africa began to speak the language, by the side of their own. If we can find out that, our conclusion must be that it is that language which became the cause of the transformation of Dutch, and that the other languages with which Cape-Dutch came into contact may have most probably enriched its vocabulary by new names for unknown things or ideas, but that their share in producing so characteristic and new an idiom has been insignificant.

The Dutch settlers looked down with contempt upon the natives, and for a long time did not even try to, or at least did not succeed in, learning their language. The intercourse which was inevitable, and naturally desired for the purpose of trading, was sought with the help of interpreters, the first of whom was a Hottentot who had in India learned something like English and the Lingua-Franca which there served for all international trade, the Malaio-Portuguese.

Gradually some Europeans however did learn the dialect of the Hottentots, but far more commonly it was the Hottentots who learned to speak something like Dutch.

Though the Colonists no doubt borrowed some words from the natives, they never spoke their language to any large extent, and there is no reason to think that Dutch was sensibly modified or—if any one prefers the term—corrupted by its influence.

Nor has either French or German left many traces in the Dutch of the Cape.

The settlement here was at first only a calling station for refreshments, etc., for ships on their way to the Dutch Indies. These ships belonged indeed for by far the greater number to the Dutch East India Company, but their crews were composed of representatives of most European nations. The language which served them for intercommunication we know from various and reliable sources, and consisted of a mixed language whose vocabulary was derived from Malay, Portuguese and Dutch.

Kolbe, in his "Naukeurige Beschrijving," tells us that the best language to get along with at the Cape, "where so many nations are

represented, is Portuguese besides Malay, which languages are spoken not only there, but in the whole of the (Dutch) East Indies," and there is no doubt that his remarks refer to the mixture of both these languages. Even in some early official documents we find remarkable traces of this dialect, when e.g. the name of the Colony is generally given as *Cabo de boa Esperance*, and when we are told of the girl *Eva*, the successor of *Harry* the first interpreter, as well as of another woman who often acted in the same capacity, that they understood "good Dutch, and fair Portuguese."

It was above all among the numerous slaves that Malayo-Portuguese served as common language. These slaves belonged to Madagascar, Ceylon, Bengal, Coromandel, Malabar, the West Coast of Africa, Angola, etc., etc., and the practical need of some common language is evident: it was found in their corrupted mixture of Portuguese and Malay, and the few but interesting examples quoted here and there in official documents of expressions used by slaves, prove that this was practically the same as that still spoken in some places on Java.

The numerous slaves imported in the middle of the XVII. cent. constituted, also by their language, a danger for the purity of the Dutch, and that the other languages with which Cape-Dutch came into being by means of promised rewards and threats of punishment to encourage and promote the learning of Dutch, but though those that had been in the country for any length of time might know Dutch, new-comers had to be spoken to in the only idiom known to both the master and the slave.

Ere long however the power of Portugal in the East Indies was on the wane, and a purer form of Malay gradually ousted the Portuguese element in the "*Lingua Franca*" here in these parts. Hence it cannot cause any astonishment to find, that—though Cape-Dutch in its structure and Grammar strongly shows the effect of the frequency with which the "*Misch-sprache*" had been spoken—the WORDS of foreign origin in Cape-Dutch are mainly derived from Malay, and, of course, those of more recent adoption from English.

To attempt a sketch of the language and its peculiarities, interesting as the work might be, lies outside the scope of this paper. If I have succeeded in encouraging students of language to turn their attention to Cape-Dutch, they can find an excellent beginning of all this in the three little books I have quoted and in the works (Grammars, etc.) of the Rev. S. J. du Toit.

There is much to be done still: fresh observations, careful study of the facts, and above all a good collection of its vocabulary are wanted. Of the latter there exists as far as I am aware but one: Mansvelt's "*Idioticon*," undoubtedly meritorious as a first attempt, but miserably inadequate for scientific purposes. Mansvelt gives no examples, no quotations to support his explanations or to illustrate the various uses of the words, and the most casual reading of any story in Cape-Dutch will supply the student with addenda. And many of the etymologies given by Mansvelt need "careful revising," to say the least of them.

## 41.—HOW WE GET KNOWLEDGE THROUGH OUR SENSES.

BY REV. F. C. KOLBE, D.D., B.A.

The purpose of this paper is, not to try to add anything to the speculations of Psychology, but simply to state one of its fundamental questions in such a way as possibly to render the science interesting to some of those to whom it may have been hitherto unfamiliar.

Philosophy has always concerned itself with questions regarding knowledge, its character, its extent, and its validity. Modern advance in biology, and the continuously increasing differentiation of all branches of knowledge, have not only tended to separate Psychology from Philosophy, but have fixed men's minds more and more on the question "How do we come to know?" rather than on the question "What is the value of our knowledge?" But mankind is too deeply interested in the results of these inquiries ever entirely to drop the What and the Whether in favour of the How. Although, therefore, the title of my paper begins with How—"how we get knowledge through our senses"—yet I take it that the further question is connoted, viz., whether it is really knowledge that we get.

Now, it is a familiar experience that in many matters by following out different lines of reasoning we can arrive, apparently with logical cogency, at diametrically opposite conclusions. For example, from one point of view matter is indefinitely divisible: from another point of view we seem to see that there must be limits to its divisibility. Kant called these contradictions Antinomies, and considered them to be part of the necessary conflict between the Reason and the Understanding when trespassing on each other's province. Be the explanation what it may, a parallel experience meets us in investigating the origin of knowledge. On the one hand, all are agreed that no knowledge comes to us without passing through the doorway of sense, and the things of sense are purely phenomenal; and following out this line of thought solely, we seem to be drawn to the conclusion that the world around us and we ourselves are all reducible to mere passing phases of infinitely varied vibrations. Vibrations of what? you may ask. Of the unknowable, is the reply of the phenomenalist: and thus we are stranded on the furthest shore of philosophic scepticism. On the other hand, every one is conscious of the continued existence of his own cognizing self; we can if we like put this mental fact in the foreground, and thus come to interpret all sense in terms of consciousness. If we pursue this line solely, we are irresistibly landed in pure idealism, where matter has no existence at all save as a phase of mind.

It is obvious that both methods are not only possible, but legitimate. If, then, their outcomes are diametrically opposite, it follows, since contradictories cannot be true together, that neither

method can be safely trusted alone. As Reid says, you may not be able to tell exactly where you went astray, but if your path suddenly ends in a coal-pit you know you have certainly gone astray.

Suppose we follow each path separately first, before we try to find some integrating method which shall establish confidence in our knowledge both of ourselves and of the objective world.

You will not expect me in this short paper to describe the senses or the nervous system in detail. Suffice it to say that we have a system of nerve centres and fibres, ramifying throughout the body, and ending at its periphery in various complex modes. Within the body, through this nervous system we become aware of a mass of vague systemic sensations, none of which are in themselves of any great intellectual value, but which taken together are as important to our mental view as the leaves of a forest are to the landscape. At the surface of the body, one set of nerve-endings enables us to perceive resistance; another, variations of temperature; another, variety of odour; another, of taste; a far more complex one, of sound; and the most exquisitely delicate of all gives us the world-penetrating glories of sight.

Now, in all this there seems to be a strange incompleteness. Our senses seem to have been thrown together at haphazard rather than systematically co-ordinated to the end of knowledge. Indeed, at first they seem entirely disparate. What, for example, is the common measure between sight and sound? An approach to an answer is found in the idea of movement or vibration. If matter be usually found in masses, and if masses be composed of molecules, and if molecules may be considered as vortices in an all-pervading ether, and if each molecule has its own characteristic internal movement, then the senses may be classified by saying that touch is massive, hearing is molecular-massive, sight is molecular-etherial, and the chemical senses of taste and smell are intra-molecular.

When we classify the senses so, we become conscious of wide gaps between them. An imaginary experiment, due (I believe) to Dauvé, will make this clear. Let us fancy we have a rod in an absolutely dark room, with preternatural means of revolving it at any speed without limit. While the rod is at rest or moving slowly, we can perceive it by touch only. At about 30 revolutions per second we begin to hear it as a low musical note, rising through the scales as the vibrations increase. Then it passes through shrillness into silence, and after a pause, when it reaches, say, 300 billions of revolutions per second, we begin to see it as a dull red light, passing through all the spectral colours, till our eyes lose it in the ultra-violet rays. A further long pause, and we can conceive the vibrations becoming so rapid as to affect intra-molecular movements, and we might smell and taste the presence of the rod,—smell and taste being perhaps as contiguous as touch and hearing.

What about the gaps in this arrangement? Is there room for other senses between hearing and sight, or between sight and smell? And might not such other senses give us a totally different world? Indeed, may we not suspect that some animals do possess other

modes of sensation than ours? If the chrysalises of a male and a female moth be separated by miles, and if, when the perfect insects emerge, the female be confined in a wire cage and the male liberated, the latter will reach the former in just about the time it takes him to fly the direct distance. The experiment was tried in England with an exotic species so rare that the identity of the male might be confidently presumed. Could this be the result of any sense we know? Many animals develop phosphorescence; some can give electric shocks; is it not possible that some of them may find their direction in space by some organ sensitive to magnetism?

Now, supposing these gaps in possible perceptive power to be filled up—supposing, for example, we became directly conscious of electric and magnetic variation as we are of variations of light—would it make a substantial difference to our knowledge? Are there, not merely qualities, but *things*, which form part of the universe around us, but which we could perceive only by vibrations in the gaps of our scheme? I am inclined to think we have reason for saying No. It is a curious fact, so familiar that we have perhaps never adverted to it, yet really curious, and bearing very strongly on the proof of the reality of an objective world, that our senses always corroborate one another. If the world were merely, as J. S. Mill puts it, “a permanent possibility of sensation,”—if it were simply a complex arrangement of vibrations in every possible phase,—I do not understand why we should not see things which we could not touch, or taste things beyond the reach of sight. As a matter of fact, however, every “thing” has some sort of appeal to all our senses. So much is this the case, that when a phenomenon appeals only to one sense, we instinctively call it an illusion. Generally touch is regarded as the chief test of reality: “we pinch ourselves to see if we are awake”; but in truth each sense tests the others.

Herein lies a hint to spiritualists. They are so anxious to prove spirituality that they fail of reality. Voices that proceed from nowhere, apparitions that evade touch, touches by agencies that cannot be seen, do not prove spiritualism; they only prove illusion, or at least something purely subjective. A truly objective spiritual manifestation, in order to be reasonably believed, must first satisfy the tests of reality, by appealing to all the senses; there would be many ways after that of proving its spirituality. I will believe in no ghost that will not come to me in broad daylight and shake hands with me and talk to me and let my dog smell his presence: let him thereafter vanish at will, or prove his spirituality as he may. As long as he imprints his form vaguely on a photographic plate, or hangs me on the head in the dark with a tambourine, or raps with invisible knuckles on a table, psychology justifies me in putting him down as either a fraud or a subjective phenomenon.

The fact of the convergence of the senses is thus a very important one. If we had more senses, we should have fuller “pencils of convergence,” as a mathematician would say. We should know more qualities, but (except incidentally) we should not know more things. Everything that is a “thing” is a centre of so many phases

of vibration that it must appeal, directly or indirectly, to whatever senses we may happen to have.

Our power of simplifying and interpreting vibrations is very marvellous. For example, the phonograph has proved that not merely the delicacies of a single voice or instrument, but the whole of the noise of a brass band or the irregular shouting of a mob, can be reduced to, and reproduced from, a single curve in two dimensions,—the most astonishing mathematical fact, I think, that I have hitherto been able to apprehend. Indeed, it is this that has given so much hope to phenomenal psychology: knowledge has seemed more and more reducible to sensation, sensation can more and more be expressed in terms of vibration, and vibration has proved to be measurable beyond the bounds of anticipation. It almost seemed as if the world, material and mental, was all shortly to be summed up in a mathematical formula.

But when we take the other path, starting from consciousness rather than from movement, from within rather than from without, things take on a very different aspect. It can be plausibly argued that the only thing we really do know first hand is our own conscious existence; and that, so far from having to reduce our estimate of ourselves to a passing combination of vibrations of unknown matter, we cannot even be sure that vibrations outside of ourselves exist at all. For what are we conscious of except modifications of our mental being? And what warrant have we for objectifying our inner experiences? Here, of course, we come to another coal-pit. Consistent idealism is one of those theories which a man can only believe while in his study chair, as Hume said. I will not quote the common-sense of the vulgar against the reasonings of philosophers, but I will say that idealism has shown itself too unreal to stand the test of thoughtful life.

The way out of the difficulty seems to lie, as I have already hinted, in the direction of integration of processes which analysis is always tending to differentiate. Our mental being is one throughout, though it, and consequently every act of it, has a twofold aspect. Perception, therefore, can be immediate,—that is, when I perceive, it is not a mere mental picture of the thing, nor a mere mental modification of my own, that I perceive; but in my own way I perceive the thing itself. One side of the perception can be analysed into material vibrations, and another side into spiritual consciousness; but both analyses can be integrated into a single act. As the same statement can be made about my very self, and as I at least know that I am real, I have very good reason for being philosophically sure that my perception is real also.

It is obvious that in so short a paper I can do no more than barely indicate the lines upon which my argument would proceed if it were allowed development. I could not hope to do more than stimulate inquiry, and this perhaps the very incompleteness of my essay may help to do. If I seem to stop abruptly, let this be my excuse.

to determine that the property outside of that line was really benefited. But they were obliged to get it; there was no other resource; so they drew this line, and they found when they came to spread the damages over it that that line was not wide enough, so they widened it again, and finally they got the money corresponding to the aggregate damages."

But this method does not seem to be very commendable from any principle of strict justice. The only other method is to go very carefully into the question how far adjoining properties are likely to be benefited by the improvement to be carried on in an area. But this method is also of a somewhat problematic and tentative character. The general experience in London improvement schemes seems to be that adjoining properties to an improved area vary very considerably as to any enhancement of their value, and that it is difficult to lay down any general principle. Victoria Street, for example, was cut through some bad slums near Westminster more than twenty years ago, but it is only within the last year or two that the slums surrounding it have begun to alter in character for the better.

(2) A second difficulty arises, that if you once admit the principle of a betterment rate on property that has been improved by a scheme, it is very difficult to oppose logically the claims for special treatment made by those who allege that their property has been deteriorated by an improvement. Take, for example, a case which is of every-day occurrence. At the edge of a poor and low class neighbourhood, which is to be done away with by the Municipal authority, there may be a pork butcher or small grocer who does a thoroughly thriving trade, especially on Saturday nights, chiefly owing to the character of the neighbourhood on which his shop adjoins. Clear away that neighbourhood, build either big warehouses or high-class shops, and this small trader is ruined. Now, if you claim compensation from his neighbours who may happen to be improved, can you refuse compensation to him if he is ruined? I admit that a case like this might occasionally be met by the answer that the small grocer should sell his property and give way to a better class establishment, and that he would get enhanced value for his property. But this does not really deal satisfactorily with the matter in all cases.

(3) Further, there is a very practical difficulty as to the date from which such betterment is to be charged, and of the time when the incidence of such betterment rate is to be decided. It is obviously necessary not to keep the possibility of a betterment charge hanging over the people for an indefinite period, though, at the same time, it might take years before it could be really seen whether an improvement to a neighbourhood would benefit adjoining owners or the reverse. As I pointed out before, the improvement in the neighbourhood of Victoria Street has taken about twenty years to make itself appreciably felt, so that it would clearly

have been unfair if during the whole twenty years an increased betterment rate had been charged on the owners of these properties. At the same time, if the surrounding owners to Victoria Street had been told at the time the improvement was made that they would be liable to a betterment charge they would probably have preferred to have the charge determined immediately, even at the risk of its being an unfair one, rather than have had to wait for twenty years or so in a state of uncertainty as to what amount would then be imposed.

To turn now to recoupment: the device of buying up surrounding property in the hope of making it pay is a somewhat crude method of preventing loss to the community. The idea of making neighbours pay for an improvement is really almost lost sight of by this method, because the neighbours who are expropriated for this object are thereby entirely deprived of any benefit from the improvement. In the abstract the principle can only be defended on the ground that the community is entitled to take reasonable means to avoid too great a loss on these public improvements, but looked at from the point of view of the individual, it no doubt has a somewhat unpleasant air of unnecessary spoliation.

Even in the most democratic countries the law has always hedged in with very careful safeguards any expropriation of private rights for any public object. It would, it is true, be obviously impossible to carry on civil government properly, if the State had not, in duly considered circumstances, the right of taking away private property for a public object; but, although this is a principle which nobody would think of cavilling at, it is also quite as clear in principle that expropriation of private rights is indefensible, except for a very well-defined public object; and even in achieving such public object the rights of property should be interfered with no more than is absolutely necessary. If this principle is not observed, a sense of insecurity may arise among the most stable portion of the community.

Still, in England—probably the most conservative country in the world in regard to the care of private rights—there is no doubt that this system of what has been called "recoupment for public improvements" has gradually established itself. The way in which it has done so is somewhat peculiar. When Bills for public improvements (under which, of course, I include railways) began to be common about the middle of last century, in the scheduling of property it became the custom, for obvious reasons, to include not merely the bare limit necessary for a railway or for cutting a new street, but also a certain margin, so as to give free play in carrying out the enterprise. Sometimes the property within "the lines of deviation" not actually required for the undertaking became quite considerable. It occasionally happened that such surplus property became valuable, and in time Municipalities began to think that this device of acquiring surplus lands originally intended by the Legislature to save engineers from being tied down too strictly, might be turned into a source of profit, which would relieve the ratepayers of some of their burden. I do not, however, think that the Legislature has ever really sanctioned the principle of recoupment in so many words,

though it is undoubtedly true that the system has been tacitly admitted. It is, I think, very characteristic of English methods of government, which are extremely illogical, and extraordinarily effective, that a concession which was simply intended to give free scope to an engineer should have developed in this way. One curious result, however, of recoupment is that it appears in the great majority of instances in England to result in loss to the public body venturing on it. The general effect of the evidence on the subject given before the House of Lords Committee in 1894 tended to shew that local improvements did not have nearly so much effect in improving neighbouring properties as their sanguine promoters were generally inclined to imagine. This fact, I may remark parenthetically, seems to confirm the idea at which I had arrived that betterment, though theoretically a perfectly fair system, would tend in practice to produce gross injustice; since judging from the fairly general experience of recoupment in England, it might very well happen that a man would find himself saddled with a betterment charge at the same time that his property had deteriorated in value.

The view I would put forward as a commendable one in regard to recoupment is that as long as property could be turned to any conceivable use in carrying out an improvement, or if it were bound up, as it were, in property which would need to be dealt with, there would be no very great practical injustice in having compulsory expropriation of it; that is, of course, assuming that a fair price were paid to the owner. It might fairly be said that it was as much a public object for the public to take precautions that the cost of a public service should not be prohibitive, and that, therefore, they were entitled to take property which would reduce that cost, and which was clearly involved, as it were, in the improvement. In this case also it should be pointed out that the individual would not be seriously damaged, though he would not be allowed to profit unduly from an enterprise to which he had not specially contributed. But when it comes to the question of how far you will extend this principle, I am free to confess that I have no more exact answer to give than that commonsense must be used. If you carry the principle too far of allowing the public body to expropriate property solely, as one might put it, with a speculative object, a dangerous sense of insecurity would immediately be created in property owners; and in all probability, though this is not exactly to the point in the discussion, the public body would find that it had embarked in a very hazardous enterprise by dealing in land. Municipalities and public bodies generally cannot be said to be very expert as a rule in the trade of money-making.

The conclusion to which I have arrived, after indicating, I fear, in a very halting and tentative manner the grounds by which I arrive at it, is that the betterment charge on people who profit from an undertaking more directly than the rest of the community is theoretically perfect. If it can be levied fairly, no conceivable objection could be brought against it, but the actual difficulties in the way of it seem to me so great that I regard this method as impracticable.

I think that a very striking proof of this impracticability from the point of view of justice is furnished by the fact that the House of Lords Committee, which reported in favour of a betterment rate in a modified form, added that, if the owner was of opinion after the betterment rate had been fixed that it was an unfair one, he should be entitled to call upon the public body concerned to buy the property at its actual market value. This, however, it is clear, is only an indirect way of coming round to recoupment.

Recoupment, as I have tried to indicate, is not very defensible from a theoretical point of view, but as a working proposition within the limits I have laid down, it seems certainly not to be unfair on the individual. Moreover, in South Africa, where the property market is less conservative than in England, and where an improvement or other alteration in value has a more immediate effect, the result would not be so disappointing to public bodies as it appears very often to have been in England.

### 43.—THE MORAL EDUCATION OF CHILDREN IN SCHOOLS.

BY REV. R. BALMFORTH.

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#### [ABSTRACT.]

During the last thirty years a great change has taken place in our conception of Religion, a change by which the practical aspect of religion has come to be more and more emphasised. Though men differ widely and irreconcilably on the theoretical side of religion—on Theology—they are in full agreement and sympathy on many things which concern the practical side—Morality, which, however, finds no systematic treatment in our schools. This change in our conception of Religion—which really means a change in our conception of Life—must ultimately affect our theories of education, which are closely concerned with the practical side of religion. We all agree that the end of education is the formation of character, and yet, while we bestow much time and labour on the physical and intellectual training of the child, we give little systematic attention to his moral training. This may be more difficult than the teaching of creeds and catechisms, but this is all the more reason why it should receive greater attention at our hands.

But can Theology and Morality—for practical teaching purposes—be divorced? We do so divorce them every day of our lives, leaving the theological sanctions to be emphasised at such times and places as may be deemed advisable. This course should be followed in our schools, so that our moral lessons might be couched in universal—not sectarian or sectional—terms, each school linking on its system of moral instruction to its religious teaching according to its particular bias.

By "moral instruction" I mean instruction and training in all those habits, feelings, and ideas which help to purify, refine, and elevate the human spirit. This is surely the great aim of education, which should gradually introduce the growing mind of the child into a larger circle of life and thought, alive and active with new suggestions, interests, and ideals, which would draw its energies into higher channels. Thus the teacher would be part of the advance-guard of the army of humanity, preparing the way for the preacher, the theologian, and the philosopher.

The full "content" of Morality requires systematic exposition and illustration, because each part and detail affects all the other parts which make up the unity of the self, and affects also the social organisation, of which the individual is a part. But the child can only envisage such aspects of the moral ideal as come within the range of its spiritual vision. Hence the moral lessons must be carefully grouped and graded to meet the growing mind and moral needs

of the child, proceeding gradually from the self-regarding to the other-regarding aspects of morality. First, personal and physical habits and duties; then the duties which relate to the feelings—filial and fraternal duties; lastly, social and civic duties. All these would naturally receive illustration from all the sources which Nature, History, and Art so richly afford.

As to the method—the teaching must be realistic and concrete—not abstract nor didactic, and should proceed by way of analysis, illustration, question, and answer; the aim of the teacher being to draw out the thoughts of the children, and to guide them, where necessary, in the right direction. This means that the teachers themselves should be trained in Ethics and in methods of moral instruction, and that they should always be required to carefully prepare their moral lessons beforehand. This would make great demands upon the teachers, but it would help to perfect or, at least, improve their teaching powers, and lead to a more sacred estimate of their high calling. The teaching itself would also lead to the segregation of backward or hardly endowed children under specially trained teachers; to more frequent conferences amongst teachers themselves; and to conferences with parents in order to bring the home training into harmony with the school life. By this means our conception of the meaning, value, and aim of education would be gradually widened, and our educational ideal transformed from that of the production of self-regarding and self-seeking units to that of the cultivation of a richer individuality seeking its highest activity and good in the well-being of the whole.

If this moral education—education in the practical side of religion—is the highest part of education, a place *must* be found for it in the curriculum of our schools. With all our reverence for scientific knowledge, intellectual ability, and technical skill, let us not forget that all these lose their value unless they are transfigured by moral imagination and guided by moral aims. And though this system of moral education may not bring the millennium, it will help the psychological balance of society to dip, if ever so slightly, in the direction of progress.

N.B.—This paper has been printed, separately, in full. Copies may be obtained from the writer (Upper Camp Street, Cape Town).

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#### 44.—THE SOCIOLOGY OF COMTE WITH SPECIAL REFERENCE TO THE POLITICAL CONDITIONS OF YOUNG COUNTRIES.

BY H. E. S. FREMANTLE, M.A., F.S.S.

It is a melancholy fact that sixty years after the publication of the last volume of the "Philosophie Positive" the name of the science which Comte thought he had discovered, and which he regarded as the queen of all the sciences (Phil. Pos., VI., 554) is still an unfamiliar barbarism, and the science itself hardly admitted into the hierarchy of sciences at all. "What is sociology?" said an office-bearer of the South African Association for the Advancement of Science, when the title appeared on the programme. As a preface to one of the new volumes of the "Encyclopædia Britannica" there is an essay by Mr. Karl Pearson, who is known, amongst other things, as a sociologist, on "The Function of Science in the Modern State" (Vol. XXXII.). In it he points out how certain characteristics are inherited, how death-rates are selective—that is, how death and certain qualities go closely together—how those who die early have few children and *vice versa*, how the factors of national strength include vital, material, and moral wealth, how all these need scientific fostering, how desirable it is that the ladder leading from class to class should be difficult to climb, how undesirable that the proletariat should be intellectual, how carefully each class in the State should be educated, and how necessary it is that there should be an aristocracy trained in State-craft. All these are matters for Sociology to discuss. It has been defined as the "scientific study of society, including all the special Social Sciences." (Dictionary of Philosophy and Psychology, ed. Baldwin.) It asks what is done in the way of association, how different races act in this respect, what different forces are at play, and by what phenomena they are attended, and what special problems society presents to psychology, to ethics, and to metaphysics.

This is a vast field of inquiry, and the subject is specially difficult to study, consisting as it does of a fleeting phantasmagoria of events which never recur. Science itself is bewildered at such a task, and there is a paramount necessity for dividing the question further. As a rule, science begins with simple questions put to it by practical experience, and, as a fact, sociology does only advance by obeying the Roman injunction, "Divide et impera." History asks how particular nations conduct their common life. Science prefers to take particular motives, and asks what will be the mutual relations of men actuated by some such motive, and how may a man with such a motive best gain his end among men of ordinary disposition. The two sciences which have been organised as a result of asking such abstract questions are Political Economy and

Rhetoric. The latter has been abandoned by Science. The former has gradually regained concreteness, and now traces the economic thread, not, as it may be imagined, apart from the actual conditions of life, but as it winds in and out through the moving and organised labyrinth of human nature. It has thus attained valuable results, and gained a generally recognised position. Sociology will never progress unless, consciously or unconsciously, it adopts a similar procedure. It is true that Comte and some other sociologists have taken a different line, and have attempted to ascertain the laws of human association by making an abstract of history in general. We shall see whether this path of investigation repays the sociologist on anything like the scale on which it undoubtedly repays the philosopher and the historian. Meanwhile we note the objection and reassert the thesis. It is also true that really sound achievements have resulted from psychological investigations into social elements of the individual and of aggregations of men. But, if this is an exception, it is one which proves the rule, since the procedure adopted is undoubtedly of the abstract kind which we suggest, and which is common to all science; that is, a particular class of phenomena is abstracted from the complex of experience and studied in isolation. At the same time, while admitting the value of such studies as increasing our knowledge of the phenomenology of the subject, we must also notice that, since the abstract social instinct does not of itself suffice to form the dominant motive of life, it can never be used as the key to the whole labyrinth. To examine the phenomenology of the abstract social instinct is useful; to ask what would happen if men were dominated by it would be foolish. Science asks many hypothetical questions, but it does not ask a hypothetical question about practical life when the hypothesis is known to be untrue. As a matter of fact, such advances as have been made in sociology have all been in the way of examining questions suggested by the practical exigencies of life; and, therefore, since men are to a great extent actuated by the crudest utilitarianism, sociology owes much to utilitarian theorists, who trace the not imaginary path of actual motives and fasten on the questions which are thrown up before them. But there is still something unsatisfactory about such a procedure; for it is attended by a sense of waste of time and effort. If such utilitarianism is meant to describe the actual motives of men its truth is limited, since many men and women are actuated by higher motives, and the world described is not therefore the actual world. Nor is there anything else to recommend the selection of this particular instinct of selfishness, since science can never be a mere pander. Apart, therefore, from the service rendered by suggesting an actual motive, utilitarianism is of no service to sociology.

Now, sociology deals immediately with human action, that is, with the phenomena of the will, conscious or unconscious, and the will is claimed in its entirety as regards practice by conscience, and as regards theory by Ethics. There is, therefore, a question which sociology must ask sooner or later, namely, the question of the right

motive in respect of social action. If we can give an answer to this question it will afford a guide such as we need, and such as utilitarianism provides, in traversing the rest of the field of sociology. It is true that all men are not guided by ideal motives, and, therefore, it would be hypothetical to imagine an entire society guided by such motives, as we have seen that it would be to imagine a society entirely guided by selfish motives. But there are two points in which the procedure of working with the ideal motive in sociology is superior to the procedure of working with the hedonistic motive. In the first place, the world in general has an interest in helping idealists, whereas, as Comte says, every egotist is a formidable competitor to every other; and in the second place, whereas there was no special reason for investigating the hedonistic motive, there is, as we have seen, a special reason for investigating the ideal motive, namely, the incontrovertible fact of the existence of conscience as a sociological factor, demanding special treatment. According to this view a complete sociology must return to the methodology of Plato and Aristotle, who founded the science of politics on Ethics, and who, in fact, did not make an absolute distinction between the two, because they both regarded Ethics as an integral part of sociology.

But if, as regards methodology, no advance on the Greeks can be made, except down a series of blind alleys, as regards the substance of sociology thought has advanced enormously. Aristotle was considerably in advance of Plato in clearness and particular knowledge; modern sociology is vastly in advance of Aristotle. After we have ascertained the ideal motive the questions of sociology will gradually become clear. We shall analyse the different forces with which we have to deal, and which we therefore desire to understand; firstly, the socio-economic forces, that is, the forces other than the purely sociological, and secondly, the sociological forces proper, that is, the general tendencies of men in, and in regard to, society.

Comte's procedure was of the kind which we have already referred to, namely, to regard history as a whole, and to attempt to use the resulting sublimates as a means to understanding man in society. In a sense Comte was, as he supposed, the father of sociology, but he had no more conception of the detailed subdivisions of the science than Aristotle or even Plato. The work of his successors in his own country, for instance, is as far beyond his own as modern astronomy is beyond the astronomy of the Chaldeans. As to his method, we have already expressed an opinion. No doubt history, including the history of our times, is the laboratory of sociology, if we add or include our own minds, without an analysis of which history is but a picture in a dark room. Comte did not realise this, but as his disciples have unanimously followed Mill in his criticism of Comte for neglecting psychology, it is not necessary to labour the point in attacking a position which there is only the reputation of one dead man to maintain, nor can we here delay to show that Comte's practice belied his theory in this respect.

But his procedure was of a kind which is still popular among certain persons known to the public as Sociologists. He did not attempt to analyse motives, or even concrete actions, but was content with the most general expression of the law of what he called Social Evolution. That law he thought sufficiently expressed by his doctrine of the three stages, which one of his most prominent followers declared to be to sociology what the law of gravitation is to astronomy. (Lewes' "History of Philosophy," 1867. Vol. I., p. 623.) But whether we regard this law as established or not, it is impossible to agree with this estimate of its importance. It cannot really be said that we have begun sociology at all if we only know that men's thoughts appear first in the theological, secondly in the metaphysical and thirdly in the positive or scientific form, or that men pass through an age of aggression and an age of defensive militarism to an age of industrialism. Such a generalisation, if true, is no doubt interesting, but it has none of that immediate relation to the facts of the concrete world which we require of a fundamental law. Nor can we even agree that Comte has anything like sufficient proof. He himself acknowledges that the law has not worked out except in the West. The yellow races are still in the stage of polytheistic opinionatedness, and the black races in the primitive stage of fetichism. It may be that the history of Europe has been determined by the essential laws of the human mind, but it is also possible that it may have been determined by tendencies which are peculiar to Europe, and, owing to his disdain of psychology, Comte has no possible means of shewing which of the two alternatives is true.

But apart from the question of the truth of the law, and apart from its unhappy and sterilising combination of extreme abstractness and want of generality, we shall find that Comte was seriously mistaken in his radical pre-conceptions, that a fundamental error led him into his faulty methodology, and afterwards, owing to the fact that his knowledge of history was insufficient to check him, gave him a distorted view of the past as well as of the present, and that in consequence no use can be made of Comte's sociology except by employing the splendid materials which are to be found among the ruins of his system in the construction of a new system. Examining these materials by the help of the methodology which we have just sketched, we shall see that the ideal which, however he came by it, Comte undoubtedly had, was in many respects a true ideal; we shall find that, in his determination of the means for realising that ideal he was again misled by his unfortunate bias, and we shall prove that there is in his mind a radical inconsistency, the detection of which is in the last degree instructive and important. Finally, we shall see that special light is thrown by new countries on Comte's sociology and on sociology in general, and that they stand in a peculiar relation to the whole science.

There are few biographies in which it is easier or more suggestive to trace the effect of circumstances on character and of character on opinion than that of Comte. His history does much to remove the repugnance excited by his style and his intellectual arrogance,

and also to clear up certain misapprehensions which have obscured his character as a thinker in some quarters where we should least have expected it. It is not necessary to minimise the difficulties. As to Comte's style, one of his most distinguished followers finds in it a certain multiplicity of phrase, a monotony, and that repetition which is only proper to oral exposition. (Harrison. Preface to Miss Martineau's translation, p. 11.) Nor can anyone fail to be irritated by Comte's pretensions, as when he announces his accession to the ever-increasing multitude of first discoverers of the fact that law can be applied to the problems of morals and politics (Catechism, p. 55), or proclaims the consummation of human progress in his own system (*ib.* Preface); or, while definitely substituting Humanity for God, waves his hand to the latter from his own higher altitude in graceful acknowledgment of his "provisional services" (*ib.* 380). Everyone, says Comte, can see illusions in every faith except his own; and the contrast between his bitterness in attacking other systems, and his easy confidence in his own does not serve to make him attractive. The whole world will be converted to Positivism, he thinks, in three generations (*ib.* 323), and the process will be specially easy with women and with the proletariat, and with the fetichists of Africa, whose humble thinkers are wiser than all the proud doctors of Germany (Pol. III., 99). In Positivism all the races of the world will be united, learning mutual respect from the recognition that it is only our pride which supposes the black race condemned to an inevitable stagnation (Pol. I., 392), and that if the white race leads the world in intelligence, the yellow race leads in activity, and the black in feeling, so that, as feeling ought to rule the mind, the black race ought to rule the world (Pol. II., 462). Universal sanitation and judicious intermarriage will complete the amalgamation of the races (Cat. 328). But it would be unworthy to pay much attention to Comte's egoistic exuberances. His history accounts for many of his extravagances, but it also helps us to see in him so much that is admirable that it teaches us to forget the whole of them.

To begin with, despite the contentions of Mill and others, Comte certainly had the virtue of fundamental consistency between his different periods. His political system was at any rate no after-thought. Nothing can be more astonishing than to turn from Comte's later works to his first essays in which we find the unmistakable seed of all his last work. Comte's writings, so far from being casual, were the necessary evolution of a mind, the elements of which, though some of them may have developed later than others, were all present before he came of age, and moreover, were developed in a logical and necessary order, not unlike the order observable in the evolution of Plato. It is no longer necessary to insist upon this point. Comte's inconsistency was vertical and not horizontal.

The constructive tendency was strong in him from the first. An idealist, and therefore an opponent of the old regime, he came late enough never to know the confidence which the revolution inspired at its outset. He was one of the first to see that all the old

convictions, revolutionary as well as retrograde, were overthrown. (Cat. 328.) The old system was disapproved in every detail; the new was entirely without synthesis. (*Sommaire appréciation de l'ensemble du passé moderne*. 1820, p. 46.) What humanity needed was not, as kings think, to live for ever in the old wretched hovel which it built in its childhood, nor, as the peoples think, to live for ever without shelter after leaving it (*ib.* 59); but to find a new construction fitted to the knowledge and requirements of the present. Comte's constructive impulse was, no doubt, original, and it was stimulated by long association with St. Simon. An end must be put to our deplorable oscillations between retrogression and anarchy. Only Positivism or Science is truly progressive (Phil. IV., 172), and it is its business to change revolutionary agitation into organic activity. (Phil. VI., 766).

There are destructive and there are constructive periods, and among the constructive periods there are periods of detailed construction and periods of synthesis and systematization. We have seen that Comte belongs to the constructive period which followed after the great destructive period of modern times. He sympathised with the reaction at least as much as with the revolution, and speaks of Le Maistre with far more appreciation than of Rousseau. But in the passage which we have quoted from his essay of 1820 he shews that he was aware of the sporadic creativeness of the period immediately subsequent to that of the Revolution, although he was not aware of the essential connection between the two, and, like Burke, failed to see in the earlier period anything more than pure negativity. But his appreciation of the character of the period in which his youth was cast determined the form of his own creation. He felt the need of a system which should correlate the different sciences, and assert the power of the architect to quell the mutiny and anarchy of the masons. This need of a system, which is acknowledged even by thinkers like Mr. Spencer, cannot be satisfied by such an analysis as Comte attempted in the *Philosophie*. There must be a subjective synthesis declaring the attitude of man to knowledge, as well as an analysis of the general nature and laws of knowledge. Comte points out that language and learning are the instrument and the form of a real subjective synthesis (Cat. 278, 322), and as early as 1826 he had arrived at a sense of the necessity of a new European priesthood, which should teach as its dogma the several laws disclosed by the analyses of science, and proclaim the ideal of humanity as the guiding law of all our life and thought and the first conception of ideal humanity drawn out by a farther analysis of universal history. (*Considérations sur le pouvoir spirituel*, p. 214.) The necessity for an objective synthesis Comte never admitted. He would have us know the laws of phenomena, including those of human nature, but he would also have us content not even to ask of the relation between knowledge of phenomena and reality or of the existence or nature of any such underlying unity as that which was formerly called God. As an object of worship God is to be definitely displaced by Humanity. As creator and sustainer of the

world he is to be displaced by a mere blank which Comte differs from Mr. Spencer simply by not mentioning. However, as far as he goes, he was undoubtedly synthetic as well as analytic from the first.

The form of his synthesis was to a great extent suggested by the character of the past revolutionary period, and the limitations by the circumstances of his life. To a large extent self-taught, he was opinionated before he had a chance of understanding the more subtle movements of the mind. Surrounded by retrograde Roman Catholicism, he never had more than the merest hearsay knowledge of Protestantism; immersed in his own recollections of the writings of the Encyclopædists, he had no real acquaintance with the thought of Kant and his followers. The doctrine of immanence never even suggested itself to him, and he retained throughout life the conviction that Aristotle's substance was the type of all conceptions of ontological unity, and that the only possible conception of God was one which represented the world as his instrument rather than his form. Had Comte proceeded to a university he might have had time to understand the nature of the questions discussed by metaphysics, and have learned that they are questions that must be faced before the scientific mind can rest satisfied, and are not merely imagined by metaphysicians. He might then have avoided making himself ridiculous by treating all metaphysicians with indiscriminate and unintelligent abuse, and he might have anticipated his critics by discovering that a subjective synthesis which is not also objective deserves at best the epithet "provisional" which he applies to theology.

Comte is himself an object-lesson of the truth of his doctrine that science needs a philosophical synthesis, since it will be possible for us to show how his own scientific work in sociology is spoiled by the imperfections of his philosophy. But he did much at any rate to prove the claims of sociology to rank, at least potentially, as a science. He considered sociology the proper instrument to effect the reconciliation of order and progress. (*Phil. IV.*, 234.) In his first essay he ridicules the popular prejudice that it is possible to form just opinions with regard to politics without definite study, and approves of Condorcet's statement that we might as well express opinions about astronomy without special knowledge. (*Séparation générale entre les opinions et les désirs*, pp. 1-3.) He claims that morals should be founded on reason, and sociology on history, and he deplores the anti-historic spirit of modern times which amounts to an insurrection of the living against the dead. In the programme of his lectures of 1826-7 we see that he already regarded sociology, or social physics, as the crown of the sciences. In fact the outline of his system had even then stamped itself on his mind.

Comte's mind was from the first clear, incisive, and intrepid. He was dismissed from the *Ecole Polytechnique* for leading an attempt of the boys to expel one of the masters, whose conduct they considered unworthy; and he was imprisoned for refusing to enlist under the Government of 1830. (*Lewes II.*, 558, 572.) This is

perhaps why the elements of feeling which he displayed in his later works are sometimes regarded as an aftergrowth or altogether overlooked. But this is a mistake. He was passionately fond of music, and went to the Italian Opera whenever he could afford it; he had a fine voice and generous sympathies, and was noted for his rendering of the "Marseillaise"; he laid the greatest stress on the education of the feelings both in the individual and in the race. He considered dialogue an improvement on monologue as an instrument of exposition, and conceived the substitution of poetry for prose. (Cat. 19.) At the end of his life he read little but Dante and Thomas à Kempis. An account of him by an old pupil quoted by Lewes (II., 582) shows how much sensibility and emotionalism was concealed beneath the austere surface, and he admitted that he had written some passages of his philosophy "tout en larmes." No doubt the mellowing process of age was much expedited by his connection with Madame de Vaux, but the admiration for women which is so prominent in his later works is present from the first, and the influence of his mother is unmistakable, as, for instance, in his view of Catholicism.

Comte's sensibility enhances the merit of the extraordinary simplicity of his life and devotion to his calling. He lived as an ascetic and a hermit, and the nobility of his life is certainly manifested in his works. "If men could approach the work with minds sufficiently open to receive instruction from teachers whom, on the whole, they refuse to follow, capable of setting aside differences, to seize upon and profit by arguments, they would carry away from the 'Politique' many luminous suggestions, and that ennobling influence which always rays out from a moral condition." (Lewes, II., 585.) Finally, his mental power was so great and so commanding that we cannot say less of his work as a whole than what Mr. Spencer has said of his system of Positive Philosophy: "Considered apart from the question of its truth, it is a vast achievement." (Essays, III. 62.)

Comte can see nothing in the opposition to Positivism but prejudices and passions, which under different forms reject all true discipline. (Cat., IX., 380.) But when we examine his preconceptions we can see that from the start he was anything but unerring. To begin with, though he was no doubt right in maintaining the necessity of sociology, his claim to be the founder of the science cannot be substantiated. If Plato was not the founder of Sociology, Aristotle was, and Comte is behind them both in his analysis of sociological forces. If they are to be denied the honour of being the founders of sociology because they had no philosophy of history, the honour belongs not to Comte, but to the Germans. Comte was no doubt of great service in reminding modern times of the necessity of establishing the science of society, but he achieved nothing which could tempt us to forget the services of either the Germans or the Greeks. Now, it is a cardinal point with Comte that he was the discoverer of sociology, for he believes that Positivism was impossible to his predecessors because of the incompleteness of the circle of the essential sciences, on the completeness of which

Positivism depends, prior to its completion by his discovery. The dissipation of this chain of reasoning by the demonstration that there is no special reason to expect finality in Comte abolishes the *à priori* argument in favour of Positivism, and facilitates its submission to a scrutiny which Comte sometimes seems to deprecate, or rather to forbid.

Mill criticised Comte because he had no method of proof. Comte was quite aware that he had no abstract methodology, and indeed he maintains that none is needed. "The study of methods," he says, "is inseparable from that of doctrines." (Pol., IV., 200.) We need not discuss the proper method of methodology. But whether Comte was right in this respect or not, he was certainly deficient in regard to methodology itself. He leaves his readers in doubt whether he is dealing with History or Ethics, and never makes definite the subject which he is studying in sociology. In fact, he is not positivistic enough. It has been pointed out that he assigns no reason for incorporating in the final conception of Humanity only the good elements. (Caird, *Social Philosophy of Comte*, 98.) The same inconclusiveness shews itself throughout his treatment of the mind. He did not treat of methodology, and he and his followers may defend this. He did not treat of Psychology, and his disciples say it is a branch of biology (Lewes), or a new concrete science coming under the abstract science of biology (Litté). The same holds of language, of grammar, and of all the sciences of the mind. But in such detailed treatment of the ideological sciences, ideology itself is left unplaced. It may be true that he that planted the ear shall hear, but we have not accounted for hearing when we have described the physiology of the ear. Now, it is impossible to regard sociology as a physical science separate from biology, and if it is treated separately because it is ideological, Comte has erred both in not doing so and in omitting other ideological sciences. Either sociology is a concrete science under the abstract science of Biology, or there are other sciences which Comte fails to account for, and a gulf between the sciences which breaks his synthesis into two. The plain fact is that Comte was extremely ignorant of mental science, and was never thoroughly awake to its problems. His mention of "the illustrious Kant" clearly shews that he had neither studied nor understood him (Phil., VI., 619, cf. Caird, *op. cit.* 104), and in his review of his predecessors in the science of sociology he only mentions Aristotle, Montesquieu, and Condorcet. (Phil., IV., ch. 47.) His ignorance of philosophy naturally resulted in superficiality in dealing with problems of the mind. For instance, he is never tired of declaiming against the conception of causation (e.g., Phil., VI., 603), but he is quite content to account for it by itself, that is, by supposing that the whole race, at a certain stage of its development, ascribes to inanimate things the causative power which man has himself. Had Comte not despised abstract methodology he might have stopped to define the subject which sociology examines, and have started sociology on the proper track as a science essentially mental. Even if it should eventually prove possible to

discuss, analyse, and measure the physical circumstances of the mind, the essential fact must still be the mind, and not the brain. On the other hand, had Comte not been so engrossed with physical science that he forgot the existence of the mind, his Positivistic tendencies would have ensured his elaborating a truly scientific method for his favourite science.

Having closed the right road against himself, Comte attempts to proceed by applying the general laws of physics bodily to the facts of Sociology. Conformably with his decision against abstract methodology, he leaves the justification of this procedure a mere assumption. It is, according to Mr. Morley, the peculiarity of his method in sociology that he verifies historical generalisations by biological law as established. But what does this mean? Science can have no possible reason to verify its laws if its methods in attaining those laws are legitimate. No other science submits its conclusions for the approval of a sister science. If two sciences do not run in parallels, and if it is certain that they should run in parallels—a point which Comte, as a consistent opponent of methodology and upholder of a subjective synthesis which is not to be objective, does not prove, nor give any reason for expecting—then so much the worse for one of the sciences. But we cannot be sure that the older science is always right and the younger always wrong.

However, Comte pursues his way undaunted. He finds, or thinks he finds, in all human thought that there are three stages, the theological, where we ascribe agency to an external cause; the metaphysical, where we ascribe it to abstract entities or causes; and the positive, where we trace the laws of phenomena, resigning ourselves to ignorance of their agents. Each stage culminates in a unity, the Theological in God, the Metaphysical in Nature, the Positive in the subjective unity of man, and perhaps, if Lewes is to be trusted, in the objective unity of the molecular theory. (618-9.) This being so, the course of History must, willy nilly, be parallel; and on these procrustean parallels Comte proceeds to torture the facts of the past until they consent to divulge the secrets which he desires them to avouch—the three stages of human development, and the law of increasing complexity and decreasing generality. Like one diseased, Comte can see nothing but parallels. Lines which to the plain mind appear to cross each other appear to him parallel. For instance, he finds three parallel stages in all departments of history, that is, since there are five stages in religion, namely, Fetichism, Polytheism, Monotheism, Metaphysics, and Positivism, and two in human ideals, namely, militarism and industrialism, we must transform the crosses into parallels by simply calling them so.

We can thus build up a sort of system out of the materials of history. To complete the systematisation of human knowledge we require a system of systems, that is, a correlation of the separate sciences. We have already seen the nature of Comte's synthesis. He would be an agnostic if it ever occurred to him to ask what lies behind phenomena. But it does not. There is nothing but phenomena. The only absolute principle is that all is relative (Pol.

Ap. Pref. II. From essay of 1817.)—that is, apparently, merely phenomenal. The only unity, therefore, is the subject regarded as essentially distinct from the object of knowledge. As Mr. Spencer says, Comte worships the finite as the infinite. On his own principles he had no right to make a unity of the subject—that is, man, as this is ascribing unity to the race without the warrant of anything but the ideological facts which he denies. Having, by a happy inconsistency, arrived at this unity, he seeks to transfer to it all the worship which is habitually paid to God as Creator, though he admits that Humanity is not the creator. Mr. Spencer identifies his unknowable with the unity of Theology and the unity of Metaphysics, and says that it is the true unity of Positivism and Science. He is too rational to worship a concrete finite. Comte is too rational to worship an abstract infinite, and stops at the very point where his own principles are compelling him to hypostatize it.

Perhaps this review has been unduly summary. But the fact is that it is a matter of little moment whether Comte was right or wrong in his reading of history. The law of the three stages is of extremely little value to sociologists, even if it can be substantiated. The whole system of Comte's sociology has to be dissolved before its elements can be utilised at all. But it is worth while observing certain further prejudices and limitations in Comte's mind which are reflected in his particular opinions, and which help to make plain the nature of his error. First, Comte was not a scientific evolutionist like Darwin, nor a philosophical evolutionist like St. Paul and Hegel, and in consequence he had a mechanical view of development, and regarded species as absolutely distinct, and, on the other hand, stages in human growth as differing in experience, but not in mental power. So, for instance, he accounts for the alleged smallness of the number of great names in Polytheistic periods by the mutual jealousies of the priests of different gods. (Cat. 341.) This tendency naturally leads to a psychology based on a childish faith in phrenology, and characterised by the most absolute distinction of elements. The mind is almost passive in perception. As in Plato, the three chief classes in the State correspond to the three divisions of the mind, as if these had an independent existence. There is no development of the impersonal from the personal instincts, and therefore maternal love is classed as purely egoistic. Hence the strain of asceticism in Comte, despite his theoretical objections to anything of the kind. Secondly, Comte certainly had an inordinate affection for system. He likes threes, and therefore makes the relations of mother, wife, and daughter the only fundamental female relations, sisterhood being negligible as not exciting any special emotion. But, in arranging his months, he finds that there are four weeks, and sisterhood therefore reasserts itself. (Cat. 107, 110, and 131.) We need not multiply instances. There is an appearance of exactness about Comte's arrangements which is purely fallacious. For instance, he calculates the precise salaries of the priesthood without pausing to consider what effects the general arrangements would have on the value of money. He

estimates that there can be a proportion of one priest to six thousand people, though the priest is to undertake all the education, and this will mean that each priest will have, among other duties, that of carrying on the entire education of about 700 children; and he draws a precise sketch of the social structure, but makes practically no provision for professional men. (cf. *Pol. IV.*, 428.) Thirdly, Comte mistook his own prejudices for historical inductions. He fancied that the whole of the past had conspired to make France the centre of the world. Because France is weak in poetry and realistic in painting, he sees nothing admirable in the art of Europe. (*Pol. I.*, 300.) It is right that France should be a great and united nation, but in the case of other nations disruption is desirable. The High Priest of Humanity is always to live at Paris, and all the temples of Humanity in the world shall face towards it. All these points may be reduced to one. Comte was endeavouring to explain mental phenomena without referring to the mind, which alone can explain them. He was, therefore, unable to see the natural development of the mind, which fills up all the valleys between the hills of its own leading phenomena, and was compelled to explain them in artificial ways. He was thus unchecked by any really scientific method, and he therefore developed to the full all his personal idiosyncracies and predilections.

These mechanical views lead to serious results in the field of practical suggestion. There is to be absolute uniformity of education for all classes. The priests are to look with precisely equal interest on all parts of the corpus of knowledge. If ministries are constructive, oppositions all the world over must be purely destructive, and Comte owns to a secret contempt for them as such. (*Cat. 6, Pol. IV.*, 472.) He glorifies the Czar, Napoleon III., and "the admirable dictatorship of Cromwell." He dislikes the revolution, and detests popular election. Rousseau is purely negative; the parliamentary system is a mere disguise for anarchy, and is the nurse of hypocrisy. (*Pol. IV.*, 496.) Americans are the most anarchical of Occidentals. (*ib.*, 495.) There ought, in fact, to be an absolute separation between the classes of governors and governed. Besides these, there must be a separate priesthood; it is the worst fault of the fetich period that it produced no priesthood. Priests are to consider the future and the past, politicians the present. Priests are to promote good instincts, politicians to check bad ones. The priests are to have knowledge, but not power, and it is a serious fault of monotheism that its priests, speaking in the name of Omnipotence, cannot limit themselves to their proper function as advisers. The priests of Positivism can do this, presumably because they represent Humanity, which is not omnipotent: they are not priests of an objective synthesis. With the same absoluteness of distinction Comte condemns Protestantism as anarchical because it appeals to private judgment; and the Christian religion, and even theological religion in general, because, in demanding a direct relation between the soul and God, it must destroy the relationship between the soul and humanity. All wealth is to be concentrated in

the hands of the patricians—that is, the wholesale merchants and bankers. The latter are to be absolute rulers. The subtlety of the world, the infinite difference between the natures of individuals, the multiplicity which marks classes and breaks down caste, were lost on Comte. A man must be one thing or the other, and every quality must be palpable. Hence Comte is a great enemy of large States. All the great Powers are to be broken up, so that the States may be small enough to satisfy the requirements of Aristotle. Patriotism much beyond the range of personal friendship is to him a negligible thing, though he does not think so of the church, which, having higher objects, should, he thinks, be universal.

Twice we hope that Comte may escape from the mechanical views resulting from his attempt to prevent the mind from being its own explanation, but each time he relapses. First, he suggests the distinction between the place of the individual in the order of personal values and that of his position in the order of functions; and he gives an idyllic sketch of the relations between the classes. But instead of developing this thought and analysing the purely mental conception of moral worth which he mentions, in despite of his own theories, he devotes his attention to the formal arrangement of classes according to the mechanical law of increasing generalisation. Secondly, we find a collision between the ideal and the practical which it seems hardly possible for Comte to overlook. On the one hand, the priests are secretly hated by the patricians and coldly respected by the people; the patricians must be induced to do their duty by motives of vulgar pride and cupidity, and the people by the modified system of payment by results, and grave faults on the part of the priests are allowed for. On the other hand, the patricians may safely be trusted with absolute material power, which they will use as patrons of the poor and the oppressed, and the priests with absolute spiritual power, which may easily be converted into material power of the most terrific kind. (Pol. IV., 335.) Had Comte noticed this, he could hardly have failed to be made aware of the existence of the mind by the sense of the contrast between the actual and the ideal. Instead, he leaves the difficulty of this co-existence entirely unresolved.

The whole of Comte's system as it stands is thus vitiated by his perverse blindness to the fact of the existence of the human mind. It is responsible for a faulty method, for a mechanical use of that method which distorts the past and the present alike, and for the closing of all the doors of escape from itself. It is easy to convict Comte of generous inconsequences, where he leaves his narrow theories and allows his natural sympathies to operate. We have already seen this in the case of his creation of a subjective synthesis. We can see it also in his earnest belief in his own ideal State. A consistent thinker, starting with his theories, would never have attained to an ideal, and even Comte does not so far forget himself as to idealise in a scientific way, but we have seen that from the first there was a double strain in him, and it is certain that, however he attained it, he undoubtedly had an ideal.

If, then, we turn aside from Comte's method, and, taking a truer method, begin by analysing his ideal, we shall get more from Comte than if we followed his method throughout. This is not the place to examine the ground and test of practical idealism. It is enough now to characterise Comte's ideal as he found it. Despite our natural expectations, we find that Comte was a humanist in ethics. He disapproved of asceticism. He hated war; he regarded suicides and duellists as the most degraded of criminals; he disliked capital punishment, though he admitted it necessary in some cases; he was acutely conscious of the necessity of definite and deliberate moral self-culture; he had a just conception of prayer; he believed in a system of education which should develop the feelings as well as the intellect and the active powers; he regarded domestic happiness as the greatest happiness in existence, and therefore desired that all should own the houses in which they lived, and he knew the inestimable worth of womanhood, and especially motherhood. His conception of ideal character was broad and deep; in his conception of education he neglected no part of the mind, and he provided for its elaborate cultivation by religious ordinances. An apostle of the gospel of humanity, he was aware that the cult of the family and of the State must precede that of mankind. Each class was to be systematically ennobled, and the good qualities which a true optimism detects in all men are to be drawn out; it is hatred, and not love, that is blind. (Cat. 292.) There is to be a peremptory demand for character in public men; but all the functions of life are to be regarded as holy orders. Finally, all are to have the salaries which are requisite for the proper performance of their work, and no class is to own any more personal view of the question. The rich need not pity the poor, for the poor will not envy the rich.

But such an ideal is not to be attained by the methods which Comte suggests. The mechanical views to which he was doomed by his deliberate neglect of the mind stand between him and the realisation of his ideal. Instead of plastic methods which may suit all natures, we are to have a universal system of education. We are to march to our goal by severely direct routes. For instance, in order to secure general ideas, our priests are to be omniscient, that is, superficially omniscient; for human omniscience is necessarily superficial. In the same way we are to have absolutism in politics and religion, instead of attempting to draw governing principles out of the minds of our citizens. We are to have distinctions between ranks, which are very nearly absolute, and have nothing of the fine gradations observable in actual ranks; only bankers are to be allowed to rule, and we are to content ourselves with the narrow synthesis of the municipality in politics, while, if we need an objective God to worship, we may toy with illusions, fancying Nature animated, and attempting to trick ourselves into adoring space, as the ground of existence demanding of men the same devotion as individuals pay to the ground of their fatherland (*Synthèse subjective*); but we may as well remember that there is no God except an abstraction of Humanity, and no background to phenomena except a blank.

There is a radical inconsistency between the conscious and the unconscious thought in Comte's mind. As far as he was conscious of his procedure, he thought that the mind could be ignored, that thought that was merely immanent and potential was nothing, that progress transcending individual self-dependence is impossible. But, without being thoroughly aware of it, he felt that the mind was the most important thing in the world, that it was more than its own actuality, that the realisable ideal, which is no more than the fullest expression of its essential nature, implied the breaking down of the walls of individual confinements, and that finally it transcended the absolute opposition between itself and the world, and necessitated the extension of its own subjective synthesis to the whole of objectivity. This is a matter of fundamental importance. Owing to the limitation of his conscious theory, he ignored methodology, adopted a mechanical and fruitless method, and having acknowledged an ideal, his conception of which contains more truth than his general system, but involves the temporary abandonment of his fundamental presuppositions, he sought to realise it by mechanical means, which were consonant with his presuppositions, but lead in any direction but that of the ideal which is their supposed objective.

A true sociology must learn to beware of the fate of Comte. It must begin with a clear conception of the method of proof, and must base itself on ideology. It will not deny the characteristic preconception of causation; it will trace out in the positive spirit the essential laws of the mind. It will demand an absolute synthesis, and it will find the only true synthesis in a theory of dynamic immanence. Applying this to psychology, it will substitute organic for mechanical conceptions; it will thus be able to explain and analyse the feeling of sociological ethics, and the ideal which it produces, and it will determine the means of attaining the ideal end by studying the sociological and socioeconomic factors affecting each case.

There is an air of finality about Comte's writings which suggests that he had some *à priori* method of argument which no evidence can rebut, and we have seen that to some extent Comte actually believed this, and to a great extent deduced what he considered sociological laws out of the generalisms of other sciences. But when we turn to Comte's detailed suggestions we see at once that he was a Frenchman and a citizen of the old world. Young countries are in many ways the best test of sociological theories. Comte was hostile to all colonial systems, and fancied that he saw them breaking up everywhere. (Pol. IV., 519.) In revenge we may say that the circumstances of the colonies do much to disprove Comte's theories. For they do not square with Comte's views, and if we must choose between the colonies and Comte, it would be preposterous to abandon the former. On Comte's shewing, there could be no reason for moral condemnation. By any other method we should be led to an appreciation of their value.

Comte never mentions the colonies with approbation. They served, he says, to complete the corruption of the Christian priest, who seconded oppression in the colonies by absurd sophistries.

(Pol. III., 576.) They corrupt older countries by exciting the spirit of military adventure, and this is indeed the object of their existence as far as their royal founders are concerned. (Ib. IV., 419.) Italy is superior to Spain because it has no colonies. (Ib. IV., 486.)

It would not be difficult to shew how impossible it is to reconcile this description of colonial origins with the facts. But it is more important to point out the utter unsuitability of Comte's system to the circumstances of colonial life. To begin with, Comte's arrangement of the internal structure of states is unsuitable to the colonies. In them circumstances change rapidly, owing to the sparsity of the population; a man may have to be prepared to turn his hand to many things. He unites in himself several functions. It is impossible so to sub-divide labour that there shall be self-contained classes for each department. Most citizens are also soldiers; many priests are also carpenters and doctors; it is not long since old soldiers were commonly teachers; and the distinction between the merchant and the man who works with his hands cannot always be maintained. Further, a young country cannot at first afford a special class of learned men, or of politicians, while its political problems are far beyond the powers of bankers to adjust. The only hope, then, for young countries is that wisdom may be found among a class which cannot be spared from practical life so wholly as to devote itself entirely to searching after it. The distinction must be between elements in the individual mind and not between actual individuals, and the conception of immanent thought, which Comte altogether neglected, becomes a practical necessity. Democracy is thus the natural form of government for new countries. The varied needs of the population confirm the first part of Comte's early view that the people should be enabled to voice their desires, and so render absolute government and oligarchy unsuitable, while the paucity of men makes the rise of a special class of wise counsellors impossible. (*Séparation générale entre les opinions et les désirs.*) The justification of democracy is that it tends to bring out the universal elements of reason and will which are common to men, and so through democracy the colonies correct the extreme individualistic atomism of Comte's psychology.

If the internal structure of colonial society is essentially discrepant from Comte's ideal, their external relations are no less so. We have seen that Comte disapproved of the existence of colonies; but mere disapproval is futile, at any rate, as regards colonies which have established themselves in countries genuinely fitted for white men. Adopting Comte's method, there is no way of proving the point; according to the method suggested here there is a way. Comte conceived of small, self-contained, and independent states, but in a new country this would mean stagnation. Each colony would be divided up into ten or twenty small states, none of which would have the resources to do much for the development of itself or its neighbours. Co-operation would become necessary, and co-operation would tend to mean organisation, and organisation federation. Thus the circumstances of young countries seem to demand

large states. But young countries are even less self-supporting than old countries. They are thus compelled to enter the universal society of nations, which may not have a fixed organisation, but which tends inevitably in the direction of such organisation, and they are usually members of a smaller society which is organised. All such organisations simplify the more general relations of the world, and are therefore good in themselves as an approximation to the complete organisation of mankind. Comte was wrong in supposing that civilised countries could exist without purely business relations with other countries, and he was wrong in supposing that membership of a larger unity necessarily conflicted with internal corporate life and patriotism. The world's experience of federation is not very large, but it seems large enough to shew this quite conclusively, and it is a question of special interest to young countries, because of the disproportion between population and territory which we have already mentioned and the consequent necessity of devolution. Once more Comte's atomism gives way before a more organic conception.

As to Comte's general prejudices against colonies, they are probably attributable to grave limitations in his knowledge. However this may be, there can be no doubt that, whether actually they do so or not, young countries can afford to read old countries many excellent lessons. If their resources are limited, they are without many of the ailments of older lands. If they have not all the valuable elements of older societies, they are more free to raise a social system, if they choose to do so, on purely idealistic, that is, scientific, lines. They are unhampered by the immediate pressure of fashions, which are universally reprobated, but lie too heavily on old countries to be removed. As a rule, they are comparatively free from the cure of militarism, and can therefore occupy themselves almost exclusively in developing their real resources. It is easier for men of all nationalities to settle in new than in old countries, and thus valuable elements are easily added to the national stock. As to the influence of the white races in the colonies on other races, it is probably too early to speak definitely. Certainly it is possible for Europeans to add very greatly to the numbers and the intelligence of their coloured subjects. But no wise man would at the present time attempt to sketch an ideal or to prophesy an actual future for the black races. Finally, we should add that the smallness of population in young countries tends to focus social and political questions, and to make it easier to take a comprehensive view of national life than it is in old countries. It is a truism that the immense political acumen of the Greeks was essentially connected with their system of city-states. It is customary in a materialistic age to expect superior political wisdom in the citizen of the bulkier state; probably the truth is the reverse. The colonist who follows closely the events of his time probably knows and understands far more about politics than the European of equal attainments. It will not be surprising if before long new countries lead the political thought of the world.

But if young countries have special aptitude for sociology they also have special need of it. New questions of extreme gravity and

complexity have to be faced. If new countries are free from bad traditions, they also lack the sustaining power of sound traditions. Such traditions grow up, no doubt, especially in a landed population, but until they have grown up there is likely to be, under ordinary circumstances, a formidable amount of genuine anarchy, and the influx of new-comers is always sufficient in a new country to constitute a perpetual class of unabsorbed aliens and to create an undesirable line of cleavage. Acknowledging that Comte was wrong in basing his whole system of sociology on an analysis of human history, we cannot but agree with him in regarding continuity of national life as a matter of vast practical importance, and acknowledging that he was wrong in thinking that in the case of colonies such continuity is necessarily broken, we see that he can only be refuted by shewing that the immanent continuity may become an operative continuity as a result of special efforts on the part of colonists to grapple with this special difficulty. Many Americans know more of England than the English, and of Europe than the Europeans, and it is a truism that the consciousness of race is stronger in Englishmen in the colonies than at home. Unfortunately, this effort at continuity, admirable as it is in its way, is not often exact and strenuous enough to maintain the living essence in preference to the set form of the national spirit, and therefore colonies can only escape from Comte's general condemnation by a determined endeavour to understand and establish the open channels through which the life of the old world can flow naturally into that of the new, and create a real continuity underlying whatever differences of form the new circumstances may determine. Finally, for the reasons we have already mentioned the labourers are necessarily few, and the general standard of education in the upper classes is lower, especially among boys, than in old countries. On those, therefore, who have the power to study the sociological questions of a new country rests a great load of responsibility, both to their country, which desires to see its way open for expansion, and to the world, which is anxious to welcome an accession to the number of its nations, and may hope to find in the solution of the political problems of a new society some remedy for the national maladies of older peoples.

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## 45 —THE LESS KNOWN RUINS IN RHODESIA

BY FRANKLIN WHITE.

Rhodesia is the fortunate possessor of a series of relics of past ages which are of great interest to Archæologists, as they afford studies of a special type of buildings.

The absence of inscriptions, of articles typical of any special epoch, or of definite references in ancient records, makes the study of these ruins doubly interesting, and affords ample scope to the imagination of the enthusiastic investigator.

These ruins are spread, speaking broadly, over an area lying between  $18^{\circ}$  and  $22^{\circ}$  South latitude and  $27^{\circ}$  to  $33^{\circ}$  East longitude. A rather scattered line can also be traced farther Northwards, and probably communicated with the Zambesi through the Mazoe Valley.



REGINA RUINS. REMAINS OF STEPS LEADING TO CIRCULAR PLATFORM.

It is reasonable to suppose that in the comparatively unexplored country lying between  $33^{\circ}$  East and the sea coast more ruins will be found on or about  $22^{\circ}$  South, completing a line of communication from that important section of ruins to a suitable port, either at Sofala Bay or farther South. Even if the ancient builders

of these ruins did not actually sail up a portion of the great Sabi River, a glance at the map will shew that the ruins at present known are found either in the area drained by the river and its tributaries or easily accessible from these.

The general and characteristic features of these ruins have often been described. Messrs. Bent, Willoughby, Schlichter, and latterly Hall and Neale, F. P. Mennell, and the writer of this paper have all recorded their observations. It is not necessary therefore to enter into details respecting the ruins already described, but a few general and characteristic features may be referred to with advantage.



REGINA RUINS. PORTION OF GOOD WALL.

Messrs. Hall and Neale have given in their "Ancient Ruins of Rhodesia" a list of more than 120 localities in which ruins, some large, some small, are reported to exist. The size of some of these ruins, such as Zimbabwe, Mundie, M'Popoti, Chum, Dhlo-Dhlo, and Khami indicate that they were important centres, the first being by far the greatest. They controlled an area 180 miles long by 100 miles wide. Numerous other minor ruins, some forts, some centres of mining or trade, some merely guard-houses on the line of communication, are scattered over and extend considerably beyond this area.

As a general rule the larger ruins are situated on or near the granite area, and occupy commanding situations on the kopjes or bosses, the huge scattered boulders being frequently used to form part of the walls, which must have been erected for defensive purposes.

The blocks of granite used in the walls of these ruins are, as a rule, 7 to 11 inches in length, and  $2\frac{1}{2}$  to 5 inches in thickness, roughly worked into rectangular shapes. The lower courses of some of the higher walls are often built of larger blocks.



REGINA RUINS. PECULIAR FUNNEL-SHAPED HOLE BUILT UP THROUGH RUBBLE FILLING IN A TERRACE. IT LEADS NOWHERE.

The blocks are carefully laid, and are generally in regular courses. In walls of the best class the joints are generally broken. There is no regular system of bonding courses. Many walls are faced on both sides, the interior being filled up with loose rubble, evidently the rejected pieces of stone. No cement or mortar was laid between the blocks. As a proof of the excellence of the work, the walls of the "Temple" at Zimbabwe can be cited. They are in parts 30 feet in height, 16 feet thick at the base, and stand as firmly to-day as when they were built.

In a few districts diabase blocks were used, evidently in the absence of granite. In others this rock was evidently introduced as an ornament. Slabs of black or dark red ironstone shales were frequently used for ornamental courses, or for forming variations of some of the patterns built in the walls.



REGINA RUINS. PORTION OF WALL SHEWING CHEVRON, SLOPING BLOCK, HERRING-BONE, CHECK PATTERNS; ALSO COURSES OF DARK STONE.

As a rule, the walls of these ruins ran in an irregular manner round a suitable granite boss, one axis being longer than the other. An irregular elliptical figure would thus be formed.

The best built ruin discovered, called the "Temple," at Zimbabwe, is a fairly regular elliptical figure about 300 feet by 230 feet, but it is by no means so regular in its curves as some would have us believe, and although several ingenious and interesting theories have been advanced as to significance of curves, of orientation, of the special object of the ornamental work in the walls, of apertures or entrances, and as regards standard of measurement used, it is far from being proved that these theories are based on satisfactory data. On the contrary, Mr. F. P. Mennell, in a special report written for the Rhodesian Museum, on the Zimbabwe ruins, distinctly states

that his measurements of the celebrated cone in the Temple differ materially from those given by the late Mr. Theodore Bent, and on which the latter founded his theory that the unit of measurement was the cubit of 1'717 feet.

No ruin has yet been found of a square or rectangular form. Square corners or straight walls occur in comparatively few instances. They are considered (Hall and Neal) to indicate ruins built, wholly or in part, at a later period than those characterised by round ends to the walls and entrances. They certainly are more elaborately ornamented. About 10 per cent. of the ruins have these square ends and corners.



REGINA RUINS. SHEWING FOUR TERRACES, BUT OF INFERIOR CONSTRUCTION.

The entrances were often covered in. At Zimbabwe passages or openings through the walls can be seen, the roof or top being supported by beams or slabs of stone. In the entrances of other ruins stout hard wood posts still often remain, which evidently carried beams with the same object. These posts lie partly in recesses left in the wall when these were built, as the blocks are carefully laid against the timber.

A theory has been advanced that the entrances to these ruins look towards the rising or setting sun, and indicate some form of solar worship, but, as a fact, the entrances point to all parts of the compass, and were evidently placed where most suited to the special locality or site.



KHAMI RUINS. SQUARE ENTRANCE IN SMALL RUIN.

In what are considered by some as the older type of ruins the walls generally run in one face from the foundations to the top. In ruins of the "later periods" the walls are built in two, three, or even four tiers, stepped back, and forming terraces 2 to 10 feet in width, and originally covered with a concrete or cement pavement, made of crushed burnt granite. A ruin of this class has a very imposing appearance, especially, as is often the case, when there is abundance of ornamental work in the walls.

In some ruins a narrow passage between strong walls runs from the entrance to the centre. In the Zimbabwe Temple there is a notable example of such a passage, and the passage leading to the "Hill Ruins" winds between boulders and along faces of rock strengthened where necessary with walls and buttresses until it is practically impassable to an enemy armed with bows and arrows, spears, swords, etc.

In many ruins the original floor level was considerably below the present level. Instances are reported by Hall and Neal of successive layers of concrete floors one above the other. As in some cases skeletons have been found between these layers, it is inferred that important men were buried in this manner, the new floor being used until subsequent interment made another layer necessary. This may have been the case to a certain extent, but it is also quite clear that many ruins were partly filled up by Kafir tribes and used as sites for their huts or kraals.

As there is no evidence that any of these enclosures were roofed over, it is conjectured that the old builders lived in circular huts with clay or concrete walls, strengthened by hard wood posts, the roof being probably of grass, and of the beehive type.



KHAMI RUINS. RECESS OR RIGHT ON MAIN ENTRANCE.

Platforms of nearly circular or rough oval shapes are found, covered with concrete, and sometimes approached by two or more steps running all round the platform. These steps are generally formed by a roughly laid ring of stones covered with a thick layer of concrete, rounded off at the edges. The same class of concrete is often found, covering over, to a thickness of 5 or 6 inches, the more roughly-built interior walls, and as the concrete is coloured dark red, the general appearance of these buildings when in good preservation must have been very effective.

Many of these ruins have been inhabited by successive tribes and generations of Kafirs, and it must therefore be expected that their refuse will mix or cover those heaps left by the ancients, and it is possible that relics of the people who were dispossessed by the ancient builders will be also found on the same sites.

The characteristic feature of these old buildings is the way in which they are ornamented. This is chiefly done by leaving spaces in the courses, by introducing sloping tiles or thin slabs of stone of different colours or by laying courses of a different coloured rock.



KHAMI RUINS. MAIN ENTRANCE, LOWER PART.

The distinct types of ornamental work are generally recognised to be as follows:—

- The Dentelle.
- The Chevron.
- The Herringbone or double line of sloping blocks.
- The Sloping block.
- The Check or chess board pattern.
- Courses of different coloured rock.

Some writers are disposed to attach special significance to the presence, position, and extent of the ornamental work introduced into the walls, but in the number of ruins now examined there does not appear to be sufficient uniformity in occurrences to warrant such conclusions.



KHAMI RUINS. PASSAGE AT UPPER END OF MAIN ENTRANCE. SHEWS  
CONCRETE FACING STILL STANDING ON RIGHT SIDE.

The "Dentelle" pattern, which is the most uncommon, is formed by placing blocks with an angle facing outwards, as is often done in modern brickwork.

The "Chevron" may be described as an inverted V (the apex upwards). This pattern is not common.

The "Herringbone" is made much in the same way, the V's lying sideways, and one following another in this manner: <<<<<< At times the slabs or tiles of each < or the <'s themselves will be of granite or of ironstone, or a section of granite tiles will be followed by one of ironstone. In other cases the herringbone will extend for a long distance, and in others again it will be separated by one or more full-sized blocks of granite being introduced.

The "Sloping block" pattern is varied in much the same manner.

The "Check or chess board" pattern is formed by leaving out alternate blocks, the dark cavity remaining forming a marked contrast with the grey face of the wall. From one to nine courses will be so treated, and the effect produced is very striking.



KHAMI RUINS. HERRING-BONE PATTERN.

A special style of ornamental work can be seen at Zimbabwe, where large beams or posts of granite and soapstone have been fixed into the top of some of the walls, generally in an inclined position. Early visitors to these ruins report the existence of a larger number of these "monoliths" than can be seen now. They probably have a special significance. Great care must be observed in discriminating between the objects found in these ruins. They vary from the iron skeleton frame of the modern umbrella to the stone implement or arrow head of the possibly most ancient inhabitant of South Africa.

Messrs. Hall and Neal give a detailed account of the most noteworthy articles which have been found, and these embrace:—iron and brass cannon, silver utensils, crockery, glass, beads, etc., indicating the presence of, or occupation by, the Portuguese; iron and copper articles, such as bangles, assegais, etc., supposed to represent comparatively recent Kafir occupation; worked gold in plates, bangles, beads, wire, tacks, ferules, etc., which are considered to be typical of the ancient builders, who, in search of the precious metal, penetrated into the, to them, uttermost part of the world.

The question as to who these builders really were is one which cannot be dealt with in a paper of this description. The absence of clues to guide the investigator is remarkable. The age of the ruins

can hardly be determined by the state of preservation of the stone and wood used in their construction or by the vegetation growing in or round them.

The early Portuguese explorers refer to them as being at that time (sixteenth century) objects of a mysterious origin.

The discovery of beads, gold work, roughly carved stone emblems, etc., is claimed by some to establish their antiquity beyond doubt on account of the similarity between them and what are found in Egypt and Arabia, but it must not be forgotten that these articles may have been brought from Northern Africa by Arab traders or by migrating tribes in comparatively recent times.



KHAMI RUINS, LONG HIGH WALL. CHECK PATTERN.

Messrs. Bent, Swan, and Schlichter claim to be able to determine the date of the erection of these buildings by the orientation, by the disposition of certain portions, stones, and monoliths, which they consider have special significance as indicating knowledge and practical application of astronomical principles. Others prefer to base their conjectures as to the probable age on passages from ancient writings, both Biblical and Pagan.

The scientist without hesitation mentions a possible 1,000 or 2,000 years B.C. The ordinary observer, seeing a post still standing in the position in which it was evidently placed when the walls were built, finds it difficult to believe that even in the dry climate of these uplands the hardest wood could exist for such a period.

Apart from the interest which the investigation of these ruins will afford to the student of the history of this continent, there is a wide field for the speculations of the Astronomer, the Anthropologist, and the Antiquarian.

The Zimbabwe ruins are now being carefully explored by Mr. R. N. Hall, under the auspices of the British South Africa Company, and the thanks of all those who are interested in the early history of South Africa are due to the Company for the liberality thus displayed.

It is possible that some articles or indications may be unearthed which will assist those who have studied these questions to arrive at some conclusion as to the age of these ruins, but it is to be hoped that a tight rein will be kept on the imagination.

In order to give a better idea of the form of these ruins the writer has much pleasure in presenting the Association with plans of the Khami, Dhlo-Dhlo, and Regina ruins (the latter surveyed by Mr. Jas. Anderson), with various photographs shewing different notable features in the walls, and with a sheet shewing different types of broken pottery found in refuse heaps.

The writer, in conclusion, desires to acknowledge his indebtedness to the authorities to whom reference has been made.

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## 46.—THE LIFE OF THE CITY.

BY FRANCIS EDWARD MASEY, F.R.I.B.A.

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The title of the remarks which I offer for your consideration is, I admit, a spacious one, for the subject is of such vital importance under modern conditions of living as to deserve a Congress entirely to itself, and that continually sitting.

It would be, however, neither appropriate nor possible on this occasion to deal with other than one aspect of this subject, namely, a consideration of some of the contributions made up to the present time by physical science towards the solution of the problem, for the existence of which it is admittedly largely responsible, namely, in the promotion of physical health in the city life. This I divide for convenience into two heads. Firstly, some consideration of the knowledge placed at our disposal by the discoveries of Science during the past century, and then some suggestions as to how this knowledge may be best turned to practical account.

The enquiry is a complex one, for we find on one hand practical science bringing within reach of all undreamed-of opportunities for human development, whilst on the other the deteriorating effect of modern city life which the development of that same science has called into being, and which seems to be threatening not only the health, but the very existence, of our race in its higher developments.

Applied science, however, having come to stay, with its factories and mines and machinery and countless other accompaniments born of chemical and mechanical inventions, it is for us to determine whether their present detrimental effects upon physical health are a necessary condition of its existence, or whether they result from an imperfect and unscientific relationship, which, although clearly remediable, is allowed to exist between it and ourselves.

Whatever be our conclusion, our clear duty is to endeavour to shape the industrial conditions of human life in cities so as to as far as possible counteract their deteriorating tendencies.

To realise that the burning importance of this subject has not entirely laid hold of the mind of the urban committees, we need not look far for symptoms, such as the languid interest shewn by citizens in Municipal government, the tendency of Municipal Councils to limit their activities to such elementary, though essential duties as drains, water, and street paving, the absence of any *compulsory* standard of proficiency in sanitary science in two such important occupations affecting the health of the community as Medicine and Architecture, and, above all, in the permitting of private interests to disfigure and injure the city to the detriment of the community without effectual hindrance.

The principal directions in which perhaps more conspicuously the application of scientific methods towards ameliorating the conditions of city life may be considered as follows:—

(1) The orderly and sanitary planning of the city in regard to sufficient width and useful direction of the streets, and the proper construction of the same.

(2) The planting of trees in the streets.

(3) Cleanliness of the streets.

(4) The desirability of acquiring land for the poorer classes which may be unsuitable for other purposes.

(5) Hygienic regulations for the exterior and interior of buildings, including the forbidding of the erection of buildings contrary to the official building laws, the forbidding of the erection of buildings in unfinished streets, or the following of trades within the town which may be noxious to the public health, and of unhealthy dwellings and overcrowding.

(6) Adequate provision for the supply of water and lighting.

(7) The provision of suitable building plots in sufficient quality and quantity, and control of the hygienic arrangement of buildings, workrooms, and dwellings.

That these greatly to be desired objects may be carried into effect a number of measures of both a private and official character are necessary, such as the establishment of a comprehensive building plan, including a uniform project for the improvement of traffic. The power of providing streets and open spaces should private enterprise fail to meet the demand, including the acquisition of land for the dwellings of the poorer classes which may be unsuitable for other purposes.

(1) As a first condition of healthy life may be put the thorough intersection of the city by wide streets. This is a measure difficult to accomplish except in a modern town, and consequently gives such a first claim for preference as a desirable place of residence over one of ancient foundations, with necessarily tortuous and narrow thoroughfares. That this is felt may be seen in many cities in Europe, where quite heroic efforts are being made by the Municipalities to bring their city up to date in this one of the most essential of all health conditions. In the South of France the nucleus of some of the principal towns has been determined by the fact of their having been Roman encampments, which happy condition of birth can be noticed in the central open space and the symmetrical plan of the streets surrounding it. More often, however, we can trace the city's growth from the Church, of which it forms the centre, which, becoming famous, the lanes and bypaths across the fields leading to it, have slowly become peopled and transformed into busy stirring streets. Perhaps the most wonderful instance of the successful bringing of a city up to modern conditions exists in Paris, where an unhealthy, overcrowded, and inconvenient tangle of lanes and crooked streets was transformed in comparatively few years by a strong hand into the finest and most scientifically planned city in the world.

English towns and cities are, perhaps inevitably, as due to the condition of their development, the least scientifically planned in Europe, and this may help to account for the comparative indif-

ference and absence of ambition concerning the vital needs of a city, which exists so commonly amongst our own people.

In order to carry out the first of these essential measures for the city's well-being, we would strongly urge the necessity for the Municipality to compile an official and comprehensive building plan for the extension of the city, as well as for the improving of existing thoroughfares, when opportunity offers. Where expropriation becomes necessary, the ground required should be valued by a Board of Arbitration appointed for the purpose, as in Paris, and paid for and applied to the public benefit in the direction desired. Hardly to be separated from this point is the equally vital one of the necessity of scientific tree planting.

(2) There are two kinds of public tree planting desirable, namely, the provision for parks and the planting of trees and shrubs in the open spaces and streets. The paramount claims of this subject to recognition is perhaps difficult to realise by those born in a Northern clime, but needs no demonstrating to those who have lived in the South of Europe, in corresponding latitudes to our own. Apart from the direct contribution to the health of the City by growth of well-nourished trees of suitable kinds, there is another practical reason for their presence—in order to give shelter to both man and beast in the wide and more exposed streets and the open spaces, permitting them to be traversed without the dangerous plunge from shadow into sunlight, which all who live in a sunny climate know the necessity of avoiding.

In a city of moderate size, with ready access to the environs, parks are of less consequence than wide streets and spaces shaded with trees. In many towns where private ground has been allowed to swallow up open spaces which the Municipality has not succeeded in keeping open for the public benefit, a feeble concession is sometimes made to the claims of the community by diverting some waste and comparatively cheap land lying towards the edges of the City into a public park, a concession which is often quite inadequate from a hygienic standpoint, for the spaces to be effectual must be evenly distributed and near the heart of the city. We need only take London as an example of this. In spite of the unsanitary conditions ruling in immense unventilated tracts of houses in the poorer districts, it stands high in the European scale for percentage of open spaces, owing to the three or four huge parks grouped at the west end of the Metropolis. Professor Stubben, of Berlin, an eminent authority, calculates that a minimum of 5 per cent. of the city area should be reserved to parks, and another 5 per cent. for planting trees in streets and open spaces, the remaining 90 per cent. being apportioned 60 per cent. to houses and 30 per cent. to streets. These figures are not arrived at at random, but based on the plan of some of the principal German cities. They have been acted upon in the extension of Cologne, and may be interesting to those who have had the privilege of travelling in Germany and seen the perfection of comfort, health, and beauty achieved in this and other directions by the application of a little practical science.

(3) The cleanliness of the streets should be the pride of a well-ordered city, its observance contributing, as it perhaps does, more directly to public comfort than any one other condition of city life. Unfortunately, it is the most difficult duty to perform effectively, including as it does the dealing with storm water (in Northern countries snow, too), and the removal of refuse of all descriptions from houses, as well as streets, and their sweeping and watering during all seasons of the year, the proper performance of which requiring an organisation as complete as an army corps.

In South African towns, it is true, there is no snow to deal with, but there is something scarcely less formidable, *i.e.*, the rarity of any complete system of drainage, except in the largest towns, which involves, of course, a great additional tax on the resources of the Municipal organisation. The contributions of practical science to deal with these problems are manifold, such as the distribution of a water supply, appliances for cleaning and watering the streets, refuse destructors, and improved forms of paving, and many forms of sewage disposal.

The item of paving alone deserves far more consideration than I am able to here give it. That its importance is recognised is shewn by the attention which it has attracted from practical scientists in recent times, and the large amount of useful information which has been compiled for anyone wishing to study the subject. It must suffice here to say that no rule can be laid down as to the suitability of material, depending as it does so entirely on local conditions and requirements.

The condition which unfortunately largely dictates in this country the thoroughness and otherwise of the performance of these duties is the state of the labour market. These or similar difficulties exist, however, to a greater or less extent in all countries, and the resources of civilisation and science must be shewn in their successful surmounting, in view of their vital bearing upon the health of the community.

(4) The acquisition of land for dwellings for the poorer classes should private enterprise prove inadequate.

Perhaps the most telling result of the influence of practical science upon our generation is to be seen in the efforts to provide suitable dwellings for the poorer classes in our large towns. Of all the problems facing a community this is perhaps the toughest, and yet the most imperative for intelligent action. At the present moment the Municipality is the only properly constituted power to stand between the not too scrupulous land speculators and the well-being of the industrial portion of the community. As the whole industrial fabric is built on the exertion of the workers, so their health, both physical and mental, should occupy the first and constant plan in all schemes for municipal improvement.

It is only necessary to compare the slums of back to back houses in our large towns of fifty years ago to a modern Rowton house to see that some potent influence has been at work to produce in a comparatively short space of time such a remarkable change in

physical conditions for the better. That this change may be traced directly to the growth of knowledge and consequent respect for the laws of health cannot be disregarded.

It has been laid down by a great thinker that it is the plain duty of a Municipality to provide dwellings for the humbler classes where private enterprise is insufficient. This obligation raises the City Fathers to a noble position indeed, that of being the real protectors of the poor, standing between them and private combinations, and the position is being now accepted cheerfully, and the duties discharged in a practical if necessarily experimental spirit in most of the large European cities.

In dealing with this problem there must be the usual fight between science and sentiment, although of course with the inevitable result. The respective advocates of the rival systems of "Model Dwellings" versus "Cottage Homes" continue to urge the claims of their several methods. Whilst those for whose benefit the efforts are made may still stick stubbornly to their dark courts and resist the searchlight of cleanliness and self-restraint, new generations are being born with, we hope, some germ of that instinct of self-preservation which it is the mission of modern science to endeavour to rekindle from the expiring embers of worn-out ideals which have lost their vitalising fire.

(5) My fifth note of scientific contribution to the life of the city is included in the hygienic regulation for the exterior and interior of buildings, including the forbidding of the erection of buildings within the town which may be noxious to public health, and the forbidding of unhealthy dwellings and over-crowding to cope with which what are known as municipal bye-laws exist. That they sometimes made little headway against the evils they are designed to prevent and suppress is not so often to be traced to their being somewhat ill digested and defectively administered so much as to the passive but stubborn resistance offered to those provisions which touch private interests.

In such forward cities as Birmingham and Glasgow, where the science of municipal government is beginning to be understood and its importance realised, great strides have been made in promoting the health and comfort of the citizens. In these and many other large cities good government is steadily rebuilding up what has since the Middle Ages become an almost forgotten cult, the sense of citizenship and pride in the welfare of everything concerning the city. This is, however, a plant of slow if sure growth, and patience and hope must water the soil for its successful development.

In the administering of the group of laws which I have just enumerated many trying problems must of course arise involving the question where the right of interference with private rights should commence. Where such arise, however, we have stores of practical wisdom within our reach in the records of what is being done both in England and abroad, always guarding against the snare of endeavouring to transplant municipal laws which have proved admirable

in their results in the city of their birth and adopting them under conditions and climate for which they may be unsuited.

I mention this because two useful object lessons in this mistake may be found close to our doors, and it is the plain duty to draw attention to the danger.

In building dwellings scientifically in this country there are two vulnerable points to be carefully defended, namely, the roof coverings and the soil in which the building may be placed, yet upon neither of these essentials does there seem to exist sufficiently clearly defined legislation. As to the first point the penetrating strength of the sun must be withstood if health and comfort are to exist in the home, and yet the use of what is perhaps the most inefficient roof covering is not only permitted but is practically encouraged. On the other hand, owing to suburban villages having annexed without proper consideration of local necessities, regulations intended to apply to towns, one of the most beautiful and practical roof coverings and one peculiarly suitable to local conditions, viz., hardwood shingles, are prohibited even when the dwelling may be surrounded by acres of private ground and incapable of affecting injuriously its neighbours.

With regard to the second point, although it is a matter of general knowledge that a large proportion of physical ailments come from exhalations from the soil, no law, so far as I am aware, exists compelling citizens to form solid floors such as a layer of concrete beneath the lower storey of dwelling-houses; thus one of the most important conditions necessary to our own urban conditions is absolutely non-existent, probably because the London Act of which they are a modified copy does not find it necessary for local purposes to include this provision.

We all know that ground air is generally charged with carbonic acid gas and with gases from organic matter. Sleeping rooms upon the ground floor are, therefore, a source of danger particularly, as the precaution of leaving a clear space of some feet properly ventilated between the surface of the ground and the floor (a commonsense and sanitary precaution which is observed in most warm countries where single storey dwellings obtain) is here practically ignored.

I am tempted whilst on the subject to touch upon the effort to regulate the construction of walls, the municipal regulations necessary to the requirements of cities in the North of Europe being in this as in other respects quite inadequate to the conditions of Africa.

In the London Building Act will be found a table which has been the result of many years' accumulated experience regulating the thickness of walls. This, however, it need scarcely be pointed out, has been revised and modified by influences entirely local. England is somewhat peculiar in having an almost infinite supply of first rate bricks, cheap enough to be within the range of the humblest class of dwelling, and whose quality have enabled comparatively thin walls to be built. The object of the legislation of the London Building Act is mainly to lay down what the minimum thickness of walls shall be consistent with the safety of the building. Unfortunately, this regu-

lation has been a mixed benefit, like some other special legislation. The result is that the walls of most buildings in towns are built in accordance with this minimum scale of thickness, instead of being constructed in a more substantial manner. There is this defect, however, that the table of thickness is laid down with a view to the public safety—merely—with regard to the wall's strength, whereas it must be known to most present that a wall which might be of adequate thickness for strength may be entirely inadequate to fill other indispensable conditions of health, namely, protecting the inmates from the effects of the external temperature, and, of course, conversely, preserving the enclosed air of a suitable temperature. In the case of our own city, to take an example nearest at hand, this regulation, which is none too successful in England, has been transplanted bodily to a city where the conditions are such as to demand in many respects very largely modified treatment. Existing legislation forbids a citizen to build himself a one-storey cottage of sun dried bricks even in the adjacent villages, whilst in the heart of the city it allows a factory or store to be erected having two storeys in the roof entirely constructed of wood!

It is one of the peculiar conditions of the South African climate that buildings may be constructed of sun dried bricks where no greater weight has to be carried, and may be infinitely more comfortable to the inmates, and infinitely more healthful than a thin wall of ordinary brickwork in accordance with the municipal regulations. In the case of actual city buildings the anxiety to have hard bricks in mortar is, of course, a natural one, but, unfortunately, these city regulations have been in their turn appropriated without any consideration of local conditions by the suburban municipalities, with the most grotesque results. I am not citing this example in a controversial spirit, but simply to shew the necessity for putting municipal regulations upon a scientific and commonsense basis instead of unthinkingly adopting what has been used elsewhere, that natural but objectionable tendency which is ever waging war with practical needs.

Next in importance to ensuring suitable materials for the buildings is, of course, the question of the number of inmates to be allowed in dwelling-houses. This is a very difficult subject to legislate upon, as it touches so closely upon private rights and upon matters which on the face of it are of only secondary interest to the community, and is shewn by the fact that regulations on the subject are often found to be a dead letter. Legislation in this direction comes perhaps rather near the accusation of trying to make people right thinking by Act of Parliament, and is, of course, open to considerable abuse, as it is obviously only in the case of the humbler class of the community that any interference with the private economy of a dwelling-house can be tolerated. It is a subject perhaps that will always be difficult to deal with by any direct action, because supposing suitable measures were insisted upon in other directions to ensure healthy living we should never have any fear of over-crowding. The evil among Europeans is often merely

the direct result of the high price of living owing to excessive rentals, which it is the duty of the Municipality to cope with. It is a problem which it would be comparatively simple to solve were a European population alone concerned. Unfortunately, the peculiar conditions of the South African towns impose in this direction responsibilities and difficulties which are entirely unknown in Europe, and which require stringent and firm legislation in order that the various communities which are brought together should dwell comfortably under such reasonable conditions of health as may be necessary, and with this end in view we must consider the European standard of healthy living apart from that of the native South African or the Oriental.

The present unscientific method of dealing with our mixed city population is noticeable in the way the authorities confuse the hygienic necessities of the white population with that of the black, and the black with that of the Asiatic. There is a growing opinion that there is only one possible course which will result in the health, comfort, and contentment of all, namely, the creation of distinct compulsory areas of dwelling for Kaffirs as well as for Asiatics entirely cut off under the most stringent regulations from the European quarters.

It is lamentable that although the lower branches of our industrial life here are principally carried on by Kaffir labour, year by year goes on without any comprehensive scheme being carried out to provide them with suitable locations where they can live healthily and happily without the necessity to conform to European requirements whilst harmless so far as European propinquity is concerned. A few dozen tin huts on some waste ground near the city is our only contribution to one of the most important subjects that can occupy a South African community. It is clearly in the interest of the municipality to build a town, and a healthy, substantial one, too, within reasonable distance of the city where the native can live as nearly as possible a life to which he is naturally accustomed with as little possible interference. It seems idle to point out how much more scientific it would be to allow the Kaffir to build himself a hut which is a thing of beauty and of health rather than compelling him to live in the miserable tin hovels with which he has been supplied.

It is undoubtedly one of the first duties here lying to our hand to provide not only for the regulation of the European city life but for that of the Native life and for the Oriental as well.

The Oriental question is one which could fitly be the subject of a separate paper. Those who are so anxious to hurry us into the complications of an Asiatic invasion do not seem to realise that it means the addition of another problem to the already difficult ones which confront us. For the threatened contact may contaminate equally both European and Native, and in order to prevent it, it is necessary that Asiatic locations shall be provided in every city where they are allowed to labour, Eastern habits being as they are as different from the African as the African are from the European.

There is no time to touch upon this very important question, but simply to point out the fresh complications which will arise should Asiatics be admitted in any large numbers into our South African possessions.

In the rough outlines which I gave of the duties of the Municipality, I mentioned the forbidding of carrying on of trades within the city which may be noxious to public health as yet another obligation of the highest importance, but like those I have mentioned, it is one which needs a strong Government to enforce it. The successful administration of this law may be seen nowhere better than in Paris, although the many thousands who go to enjoy its beauty and charm do not realise that the clear air and absence of soot and dirt is not due to any haphazard cause, but is one of the results of orderly and good municipal government. The practical advantage of such restriction is an asset to the city, as shewn by the enormous income which is gained from the visitors as well as the residents from all parts of the world. It is characteristic of the Parisian that he does not attempt to escape from his city at sunset which is such a noticeable feature in most of the English towns, but lives happy and content therein, and leaves it only for a short time each year, more from reasons of fashion than from inclination, whilst amongst visitors Paris enjoys the reputation of being the most delightful place in the world to live in. In this matter as in other respects, its excellent example is being followed by many of the other European cities. It does not follow of course that all occupations which are unpleasant must at the same time be noxious to health, but if the citizens wish to conserve their city as an attractive and desirable place to live in rather than to escape from, the Municipality must have authority to prevent manufactories being erected, and industries carried on which may be in any way detrimental to the above end.

Amongst the many obligations laid upon the City Fathers is the necessary one of seeing that buildings are not carried up to a height that would interfere with the proper circulation of air or to obstruct the sunshine. The old Roman proverb says, "Where the sun does not go the doctor does," and it is one which deserves the greatest respect in this country. There is a fact which is always in danger of being lost sight of, viz., that the width of streets and public places is relative, and entirely dependent upon the heights of the buildings to be erected on their boundaries. Too much stress cannot be laid upon the necessity of taking into consideration the heights of buildings when deciding upon the width of thoroughfares and open spaces for public improvement.

It may be remembered that when the Northumberland Avenue and Queen Victoria Street in London were laid out some years ago, their supposed extravagant width was criticised, whilst at the present moment, owing to their having become flanked by buildings of many storeys, they are now, instead of being wide, undesirably narrow. It must, therefore, be an essential condition in the carrying out of any municipal building plan to see that the limit for the height of

buildings be fixed, and as strictly enforced as the width of the streets. If this is not done, the most well meant efforts on paper will be abortive.

It is scarcely necessary to mention that the exquisite vistas formed by the streets of most of the Continental capitals have only been purchased by the enforcement of regulations of this description.

In considering this group of municipal laws, there is room for one which so far as I know is non-existent, but the necessity for which must be apparent. All thoughtful people must have noticed with sorrow the reckless manner in which some of the most beautiful spots in the suburbs are being destroyed by the cutting up and selling of properties in small lots without any consideration as to whether the buildings which may be erected upon them will be suitable to the locality or calculated not to injure the property of their neighbours.

Our city with its suburbs, has at present the chance of becoming the residential centre for the better classes throughout South Africa owing to its many natural beauties and conditions, and it is lamentable to think that these should not be recognised, and that we should squander our inheritance in the direction I have indicated, viz., in allowing the suburbs to be injured without regard to the responsibility which lies upon us all as citizens of keeping them beautiful and attractive as well as healthy on the public behalf. For some time past it has been a common occurrence for owners of property in the suburbs to suddenly find that property immediately adjacent is advertised to be sold in small lots for speculative building. As the rights of citizens are recognised to be protected against any injurious action by their neighbours in almost every other direction, it seems lamentable that on this most important one serious and permanent injury may be inflicted not only on surrounding property but on the whole neighbourhood by reckless and selfish speculation without the possibility of any legal action or redress.

The wanton destruction of trees which has gone on for some time in many directions continues unchecked, and in spite of the increase in the Peninsula of people of taste, who are, however, we fear not influential or numerous enough at present to effect any remedy. It seems to point to the fact that this is a matter which could also be taken on the broad shoulders of our modern municipality. In fact the more one considers the question of scientific municipal government, the larger the subject seems to grow, for its duties are now recognised as by no means stopping at matters affecting the more material aspects of the city such as buildings and streets and the control of water and drainage, but to include the erection of ample markets to enable the healthy circulation of trade in food-stuffs, and to enable the poor to obtain their necessities protected from the extortions of possible middlemen, as well as the obligation which is now laid upon them to protect the interests of the citizens by ensuring the purity of such stuffs and the accuracy of weights and measure of goods.

These are some of the leading problems which face us in regulating the life of the city, to which science has brought the most

practical assistance, although between the recognition of its needs and the administration sufficiently powerful to translate them into fact there is necessarily a gulf fixed. As it is recognised in a nation's laws that in order to be effectual they must be not only passed by Parliament but recognised and supported by the people, so a city may have the best municipal laws in the world, but they may be a dead letter unless there is sufficient power behind the administrators to have them properly enforced. It is of course obvious that the measures necessary to promote the welfare of the city as a whole must necessarily largely be done at the expense of the private interests of the citizens, and there is of course a nice question always to adjust as to where the line shall be drawn. In the case of Continental municipalities, I think I am right in saying that the infringements of the municipal laws are in many cities dealt with by the police, and although this seems to be rather a drastic measure, yet the result, so far as can be seen, seems to justify this being done.

Past experience shows us that wherever public improvements have been carried on in any large scale in European cities they have been effected by strong autocratic power rather than by a popularly elected body. To take a few instances in London alone. The parks, which are the redeeming feature of the city, and which counteract its otherwise unhealthy conditions, have, with one or two exceptions, been bequeathed to us from Royal Preserves, and it is safe to say if they had to owe their existence to municipal improvement, they would probably be non-existent. Again, in the West-End of London, in nearly all the districts where the streets are wide and well arranged, they are on estates where they have been made by private owners, mostly noblemen. Regent Street, our one street with any pretences to harmonious lines, was carried out at the instance of the Prince Regent, whilst the Thames Embankment, one of our few fine features, was engineered by that most arbitrary of bodies, the Commissioners of Sewers.

One is almost forced to the conclusion that until the community becomes sufficiently educated, the most scientific form of government, so far as the administration of cities is concerned, should partake of the nature as much as possible of a benevolent tyranny, or should that be impossible and a government by a Committee necessary, that Government must possess the widest power and the strongest possible authority for enforcing their laws for the benefit of the citizens.

It seems humiliating to have to go back here a century and a half to show what can be done by strong autocratic government. Almost all that we have in Cape Town which is worth preserving is due to this cause. The straight, well-proportioned streets of the lower part of the town, the sensible design and construction of the houses both in town and country, the beautiful groves and plantations of trees, the clear relationship established and enforced between the white and black population, and also the existence, I believe I am right in saying, of most of our best laws.

It seems in my humble judgment not out of place that the consideration of scientific Municipal Government should be within the scope of a Scientific Congress. It is surely true that Science has but as yet touched the fringe of its future intellectual possessions, and that the time is to come when scientific methods in civic administration will come closer home than has been possible up to the present, in a way directly affecting the welfare of the citizens.

I cannot but think that Municipal government in its present organisation is inherently defective from the reason that it takes no account of the fact that the administration of a large city requires the best brains, given continuously to the work by men who have the special knowledge to do so, and that this cannot be possibly obtained by voluntary assistance, however freely and generously given. It is impossible to imagine any commercial enterprise being carried on under the unfair conditions under which we expect our Municipalities to be successfully worked. When we consider the enormous sums of money which in these days pass through the Municipal hands, we cannot but hope and believe that the community will realise the necessity of paying handsomely for services to be rendered in their interests. That this would in any way degrade Municipal life is absurd. One might just as well expect directors of a large public body or the managers of a railway to give their services free as to expect Councillors to do so without payment.

It is too much to expect that the type of citizen who is to be most desired as a Councillor, namely, one who has a large business or professional responsibilities, should neglect his own business or profession for the thankless task which at present falls to the lot of those who undertake the duties of a Municipal Councillor, and it is impossible for a man to do everything that is required of him in carrying on the intricacies of Municipal Government and that of his own business with perfect success to both. The only possible solution of the problem—and it is one of the greatest importance to all city dwellers—is that wider powers of government should be extended to the Municipality, and that those who take part in its government should be offered such remuneration as the citizens can well afford to give to enable the best men to devote their entire services to the interests of the city.

In cities of old foundation like London the struggle has gone on for many years to reform Municipal government, but owing to the number of vested interests involved, with little success. Here, however, in South Africa we have an opportunity of reaping the advantages of the experiences of the Old Country and of organising matters upon a more sensible and scientific basis.

When this is done—and only when it is done—shall we expect to have a city beautiful to gaze upon, and healthy and comfortable to live in, and I believe that this most desirable consummation can only be arrived at by the growth of the sense of order and of our responsibilities as members of the body corporate, which it is the obvious mission of Education in the fulness of years to accomplish, an Education based upon the best experiences of modern scientific thought.

## 47.—GREAT ZIMBABWE.

By R. N. HALL, F.R.G.S.

Co-author with MR. W. G. NEAL of "The Ancient Ruins of Rhodesia," and author of "Great Zimbabwe," at present engaged by the Government of Rhodesia on a term of nineteen months' exploration of the ruins of the Great Zimbabwe.

*Passages*—Every writer on Zimbabwe appears to have been greatly struck with the number of passages, both at the Elliptical Temple and on the Acropolis, and with their labyrinthine character. During 1902-3 further passages were discovered and opened out, and these had a total length of 1,832 feet. The total length of passages opened out or which can be clearly traced now amounts to 5,268 feet. As is shewn later in this section, this by no means exhausts the tale of passages to be found at Zimbabwe.

<i>Situation of Passages.</i>	<i>Cleared.</i>	<i>Traced.</i>
<i>Elliptical Temple:—</i>		
Parallel Passage ... ..	193 ft.	
Inner Parallel Passage ... ..	71 ft.	
South Passage ... ..	73 ft.	
*West Passage ... ..	30 ft.	30 ft.
*South entrance to No. 10 Enclosure ...	14 ft.	
<i>Outside Elliptical Temple:—</i>		
Outer Parallel Passage ... ..	125 ft.	
*North-east Passage (remainder of length included with "Valley of Ruins" Passages) ... ..	50 ft.	
<i>Acropolis or Hill Ruins:—</i>		
South-east Ancient Ascent... ..	349 ft.	1,260 ft.
Higher Parapet ... ..	78 ft.	
Central Passage ... ..	103 ft.	
*Sunken Passage, Eastern Temple (traced further) ... ..	28 ft.	
North Passage, Eastern Temple ... ..	23 ft.	
*South Cave Passage ... ..	46 ft.	
Covered Passage (cleared in 1902) ... ..	10 ft.	
Parallel Passage ... ..	71 ft.	20 ft.
*Cleft Rock Enclosure to foot of Platform stairs ... ..	10 ft.	
Winding Stairs ... ..	14 ft.	

\* These passages were discovered in 1902-3.

<i>Situation of Passages.</i>	<i>Cleared. Traced.</i>	
Upper Passage ... ..	28 ft.	
East Passage ... ..	80 ft.	
Buttress Passage ... ..	39 ft.	
*South Passage ... ..	38 ft.	
Pattern Passage (upper portion cleared in 1902) ... ..	51 ft.	
<i>North-west Ascent:—</i>		
*Sunken Passage in Platform enclosure ...	72 ft.	
Sunken Passage through main wall ...	16 ft.	
Sunken Passage on Northern Parapet ...	28 ft.	
*Sunken Passage from Northern Parapet to Visitors' Path ... ..	223 ft.	
*Sunken Passage from Visitors' Path to Water Gate ... ..	150 ft.	510 ft.
<i>Minor Ruins:—</i>		
*Outspan Ruins ... ..	56 ft.	
Ridge Ruins, Parallel Passage ... ..	246 ft.	
*Ridge Ruins, other Passages ... ..	25 ft.	
No 1. Ruins ... ..	142 ft.	
<i>Valley of Ruins:—</i>		
*North-east Passage ... ..		600 ft.
Passage referred to by Mr. Bent ... ..		300 ft.
*Posselt Ruins, Parallel Passage ... ..	66 ft.	
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	2,548 ft.	2,720 ft.

In addition to these totals of lengths of passages cleared out or traced, there are many other passages still buried in débris, the outcrops of their side walls being seen here and there on the surface in and near several ruins. Many, of course, must be completely buried under the veld, for some were lately discovered (1903) at least three feet below the surface, with native paths crossing them in all directions, while it is quite reasonable to suppose that with the great area of ruins yet unexplored very many more passages will yet be found, especially when it is recollected that the discovery of one buried passage has most frequently led to the discovery of several side passages.

Traces of two other passages leading from the base to the summit of the Acropolis Hill have been discovered, and these remain unexplored, and each would be fully 900 feet in length, while traces of several lines of passages are to be seen encircling at various heights the south, west, and north sides of the Acropolis Hill. These also at present remain unexplored.

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\* These passages were discovered in 1902-3.

So noticeable is this feature in the main walls of the Elliptical Temple that visitors viewing the walls from the interior constantly affirm their belief that the walls have commenced to lean over towards the interior, and when viewing the exterior faces of the identical walls, declare that the walls are leaning inwards, and must ultimately fall inside the building. This is a mere optical delusion.

The main walls, portions of which are believed to have stood some 3,500 years, are, if given the same conditions, quite likely to be standing at the end of another millennium, if not longer, for the battering back is but an important element of their massive strength, and has proved to be the main factor in securing their durability. Of course, some main walls in certain places show signs of bulging out and of damage caused by earth-movements, possibly earthquakes, also by lightning, the sinking of foundations by water or damp, or growth of trees within their open dry masonry during the long period since their erection. Some faces of the walls shew a complete swagging from end to end of their lengths, and yet the batter back has preserved the walls perfectly intact throughout, with each block still occupying its original relative position. The appearance of such walls strongly suggests the effects of earthquakes, and while these earth-movements would destroy a plumb wall, a wall with a severe batter-back such as is seen in all the oldest walls at Zimbabwe would on this account be comparatively safe from such effects.

In some instances the batter-back is very severe, and exceeds that of 1 foot in 6 feet, and the native labourers can climb such with ease. Looking at the rounded extremities of any of the most ancient walls, one notices that their sides resemble the lines of a lighthouse as popularly conceived, in many instances the batter-back being more severe near the base and near the summit, and many of such rounded ends of walls, where still perfect, show very graceful lines of battering. So carefully is the batter-back worked out in the courses, that, looking up or down the face of a wall with one's eye close to the blocks, one can scarcely see a quarter of an inch of face of a protruding block out of the line of the battering.

To secure the batter of the walls the blocks are not slanted downwards at their inner side, but are laid on a true dead level, reaching from inner to outer faces of the wall, and in their outer courses their outside edges are placed back from the outer course below. So slightly do these courses recede one above another, that in the height of only a few courses it would be almost impossible to detect the presence of any battering, while it is very decidedly noticeable in the height of some few feet.

Mr. Bent's estimate of the extent of the battering of walls at Zimbabwe, namely, 1 foot in 6 feet, is fairly exact with regard to many walls, but excessive with regard to others, such as the main walls of the Elliptical Temple, while for others now in a ruined state it would appear to have been originally correct. The battering in most instances being more perceptible near base and summit than on the intermediate face of the wall (excepting the inside face of the main wall in the Parallel Passage at the Elliptical Temple), and

the summits in many cases having disappeared, the batter-back, as ascertained by plumb lines, has consequently been considerably reduced.

Where the original summits are still practically intact and where there have been no bulgings-out of the faces of the walls, and the top courses on the edges do not lean outwards, as they frequently do on account of creeper and tree growth, the 1 foot in 6 feet is frequently approached—for instance, south wall, Western Temple, 4 feet 8 inches in 31 feet; Pattern Passage, 2 feet in 13 feet. In low walls 1 foot in 6 feet is very frequently reached.

The main walls of the Elliptical Temple, as shewn in a Table of Battering, is much less than 1 foot in 6 feet, a fair average being 1 foot in 11 feet. The extent at some points is 1 foot in 15 feet.

### THE "VALLEY OF RUINS."

The "Valley of Ruins" is on the north and north-east sides of the Elliptical Temple, and is almost half-way between it and the south end of the Acropolis Hill. This conglomeration of ruins extends along the slope on the north-east side of both the Elliptical Temple and No. 1 Ruins to within sixty yards of the East Ruins, and covers an area of about 250 yards from east to west and 220 yards from north to south. This area is the upper portion of the Zimbabwe valley, which descends towards the east, the streams from this valley during the rainy season falling into Mapudzi, which runs southwards down the Schlichter Gorge towards the Mowashawasha Valley, and later finds its way into the M<sup>r</sup>Telekwe River.

Previously to 1902-3 these very extensive ruins, some of which are massive and most excellently constructed, remained not only unexplored, but unexamined, and no particulars or plan had ever been attempted to be given, all writers being content to refer to them as the "Valley of Ruins," while some writers altogether ignore the existence of this group of ruins.

Since the Occupation no attention has been paid to these ruins. No visitors', or even native paths crossed the area, nor are there the slightest traces in the shape of trenches of any prospecting for relics and gold having been carried on at these ruins. So unfrequented has it been that some fair-sized buck have been shot within the area of the "Valley of Ruins." The space covered by these ruins was found to be an impenetrable jungle of trees, bushes, and creepers. The local natives declared the place to be bewitched, and they consequently avoided it.

The "Valley of Ruins" has recently been found to consist of three groups, each of which includes several distinct ruins, several of an important character.

The area is divided as follows:—

- (1) Lower or North-eastern Section, including the Posselt Philips, and Maund Ruins.

- (2) Middle Section, which lies between the Lower Section and the edge of the slope of the land on the north-east of the Elliptical Temple.
- (3) Upper Section, including all ruins between the north-east side of the Elliptical Temple and the edge of the slope overlooking the lower portions of the "Valley of Ruins."

Before describing these complicated groups of ruins there are some features represented by them which may be mentioned:—

(a) Several of these ruins, especially those on the Lower Section, are exceedingly well and massively built, the courses marvellously true, with an absence of straight joints. The curves of the walls are beautifully designed, and are laid on boldly sweeping lines. The material employed is good, and also most carefully selected. The masonry of many of the walls in the Lower Section is far superior to that of several of the divisional walls of the Elliptical Temple and to the majority of the walls on the Acropolis.

(b) The absence of the angular style of building. Rounded entrances and buttresses and gracefully rounded ends of walls form the prevailing feature of most of these ruins. Two round towers with almost identical measurements, a dozen large and massive semi-circular platforms also form prominent features. Drains were found (1903) in Philips and Posselt Ruins.

(c) The Middle Section of the "Valley of Ruins" is poorly built, and consists largely of long passage walls. The Upper Section is well built.

(d) The discovery in the Lower Section of these ruins of beaten gold and gold tacks, decorated and plain soapstone beams, and relics of the oldest type, including the carved soapstone beam, with bird on summit—the finest specimen ever discovered at Zimbabwe—found by the author in March, 1903, point to the fact that certain ruins in this section of the "Valley of Ruins" were used for somewhat higher purposes than those of forts, workshops, or for housing slaves, possibly, as many have suggested, as residences for priests or officials connected with the Elliptical Temple, seeing that the North-east Passage directly connects such well-built and substantial portions of these ruins with the North Entrance and Parallel Passage and Sacred Enclosure, where are the Conical Towers, of the Elliptical Temple.

(e) In the Lower Section of these ruins there are no traces of either ancient or native industries having been carried on.

(f) In the Lower Section of these ruins there are fewer signs of modern or even mediæval occupations by Makalangas. On this account there has been little of the filling-in of these ruins as is to be noticed at ruins which have been extensively occupied by natives. In the Posselt Ruins, however, there are the remains of five very old Makalanga clay huts. Very few native articles were discovered here, but such as were found were of very superior make. The small extent of native occupations of the Posselt, Philips, and Maund Ruins are open to exploration, the floor in some instances being not less

than 2 feet from the surface. But being on lower ground, with a high bank of soil and granite on the south-western flank, a considerable amount of soil has silted from the exterior into some of the enclosures. The filling-in, both natural and artificial, was no more than 2 feet, as against 6 feet to 12 feet in ruins where there are abundant signs of extensive native occupations.

### PHILIPS RUINS.

These ruins lie to the east of the Posselt Ruins and west of the Maund Ruins, and form the centre ruin of the three ruins, which are built upon a line extending from east to west. Philips Ruins are 8 yards only from Posselt Ruins and 60 yards from Maund Ruins.

These ruins present several most interesting features, which may be described as follows:—

(a) The discovery in March, 1903, of the finest, most perfect, and most elaborately decorated soapstone beam, with bird on summit, yet found at Great Zimbabwe, also phalli.

(b) An excellently constructed and massive wall, built upon the plan of a section of a circle, with the centre of its outer face towards due east, and the discovery of quantities of sections of worked soapstone beams along its base, which beams are believed to have once decorated the summit of the wall, and also the oldest type of relics, with gold.

(c) A small conical tower of almost identical measurements to those of the conical tower in the adjoining Posselt Ruins.

(d) Excellent and massive character of the construction of the walls, and the numerous rounded entrances, buttresses, and ends of walls. Two drains through walls 5 feet wide, a tall slate beam as entrance lintel, with sections of slate beams similarly employed by the original builders.

(e) The almost complete absence, except at two spots, of evidences of native occupation.

*Area.*—The area occupied by these ruins is, as at present ascertained, 140 feet from east to west and 150 feet from north to south. There is no main outer wall on the south side, and it is probable, judging by wall debris, that these ruins extended some 20 yards further south.

*Main Walls.*—These extend from the west side, round the north to the south-east, the rest having disappeared, or possibly Posselt Ruins and these ruins were originally one immense ruin, when any outer wall on the south-west side would not have been required. But this could not have been the case as to a south side of the ruin, which is perfectly open from east to west.

The main outer walls average in width 5 feet to 7 feet on the floor level and 5 feet at 6 feet from the floor. In height they range from 6 feet to 14 feet on the outside and about 2 feet less on the inside level, and this is accounted for by the slope of the area upon

which these ruins stand and the silting in of soil. Some of the greatly reduced summits are 5 feet wide. The heights of the original walls are estimated to have been 20 feet.

*Construction.*—These are very well-built ruins, some portions, especially the massive wall which curves outward towards due east; the workmanship is most excellent, the blocks have been carefully selected for size, and the granite is good and even in quality. Except for one small and poorly-built buttress, the angular features of construction are entirely absent. The fine workmanship in the construction of the curved wall suggests that some special importance was attached to this structure.

The divisional walls are also well built, and are more massive than several outer walls of certain main walls at Zimbabwe.

*Curved Wall.*—This wall forms the most prominent feature in these ruins, and it at once attracts the first attention of all visitors on account of its symmetrical and massive character and the height of its present reduced summit, which is 14 feet at its summit, and which is 5 feet wide at that height. This is the highest wall in these ruins. The curve is laid on so exact a plan that it was an easy matter for a Government surveyor to definitely determine the centre of the arc. The centre of the curve faces outwards due east, and standing at the centre of the arc the extremities of the wall, which are rounded, are found to be N.N.E. and S.S.W. respectively. It is 125 feet round its inner face at 6 feet above the remains of cement flooring and 84 feet round its outer face at the same height from the ground, but the rest of its outer length are hidden behind large rounded walls and buttresses. The distance between the two extremities across the bow is 75 feet, and from this line to the centre of the curve is 23 feet. The batter-back of the wall is 1 foot in 10 feet.

The height of the reduced summit for 60 feet from its north end averages 9 feet to 13 feet on either side of the wall, but these heights are taken from raised granite cement platforms, steps, and floors, and at present another 3 feet can be added to the reduced summit of this wall. The foundation of this wall is 3 feet below the entrance floor.

The original height may safely be estimated at 20 feet above the present flooring. This estimate is justified by the great amount of wall-debris found at the base of the wall on either face. On the summit at the south end of the wall are the remains of a banquette, and these inner terraces or look-outs, almost invariably in all ruins in Rhodesia which have banquette work, are the inner portions of half the width of the summit, the front half being carried up breast high above the banquette floor. Further, the amount of batter-work in the faces of the wall would well permit of a wall 20 feet high, and yet leave a fairly wide summit. Where the entrance facing the E.N.E. passes through the wall the side walls are reduced to 5 feet in height on either side above the floor of the entrance, which is just 3 feet above the foundation of the wall. This entrance, like those in the main walls of the Elliptical Temple, is carried over the

foundation of the wall, and forms part of it. It is 2 feet wide and 6 feet 6 inches long (the width of the foundation), and has on the inside and on either side of the entrance two rounded buttresses, with portcullis grooves. These buttresses are built upon a semi-circular platform projecting 6 feet into the interior of the building, and so making the entrance passage about 12 feet in length. The floor of the entrance is covered with granite cement pavement.

One peculiar feature in the construction of this wall is that the northern extremity is rounded off, while the southern extremity, though also rounded off, is extended by a wall equally as well built, which forms a loop, turning round on an oval plan into the east face of the main curved wall, enclosing an area of 10 feet by 11 feet. The wall of this loop is well constructed, the average height being 6 feet, but on the south side it rises to 10 feet, at which point the reduced summit is 5 feet wide. The interior was filled in with stones to a depth of 2 feet, and when this débris was removed a granite cement floor was disclosed, suggestive of this loop-shaped enclosure being a raised platform similar in purpose to the platforms in the Elliptical Temple and in the Western Temple on the Acropolis. On the west of this loop are two walls, 4 feet and 6 feet high, forming an alcove. It is possible that this alcove once contained steps up on to the platform formed by the looped enclosure.

It must be remembered that the massive curved wall is not an outer wall, but one apparently built on special design so far as its plan, superior character of construction, and possible purpose are concerned. It occupies the central portion of these ruins, with its extremities lying north and south.

The purpose for its erection might possibly have been for solar and astronomical observation, and though this is a mere conjecture, the following points might lend that conjecture some support:—

(1) In close proximity to and at the northern end of the curved wall was discovered the soapstone beam with carved bird on the summit, this being the best specimen yet discovered at Zimbabwe. These relics have so far only been found at the Western and Eastern Temples on the Acropolis. Also other ancient relics of various kinds were discovered, including Phalli.

(2) The discovery under the wall-débris, which lay along each side of the wall at its base, of quantities of lengths of broken soapstone beams. Though mostly without patterns, they have all been beautifully worked and rounded with tools (tool markings of two sizes of tools, most probably of iron, were used in working the stone, and the chisel marks were done with sharp, clear-cutting instruments). These beams are believed to have originally decorated the summit of the wall, a suggestion supported by the shape and markings on the bases of several beams so discovered. No other portions of soapstone beams have so far been found in these ruins. Soapstone beams have been found in these ruins and at the three temples.

(3) The proximity of a small conical tower at the northern extremity of the curved wall.

(4) The large raised platform formed by the looped wall at the southern extremity of the curved wall and originally approached by steps, two of which still remain.

At the west side of the curved wall and at the centre of the curve is a wall 25 feet long, projecting into the interior of the ruins. This is 3 feet high at its western extremity, but its summit rapidly rises to 8 feet. It has a slight curve towards the south-west and rounds off towards the north. On its north side there is a small recess extending from base to summit, exactly similar in construction to the recesses in Recess Enclosure on the Acropolis.

On either side of this wall and in the angles formed by the main curved wall and the projecting wall are low granite cement platforms, with rounded faces. These resemble the "blind steps" found in the angles of all main ruins at Zimbabwe.

*Conical Tower.*—This is situated in the northerly enclosure of these ruins. It is still 6 feet 6 inches in height, but, according to block debris, it has been much higher. At 3 feet 6 inches above the base it has a circumference of 18 feet 10 inches. It is impossible to measure the circumference at its base, as a large rounded granite cement step extends between it and the south wall of the enclosure. The tower, which has a fair extent of batter-back, is very well constructed. It has been proved to be solid. The measurements of this tower are almost identical with those of the conical tower recently (March, 1903) discovered in Posselt Ruins, which immediately adjoins these ruins. Its foundations are 9 inches below the granite cement floor which surrounds its base. There are four small conical towers at Zimbabwe, of which three were discovered in 1903.

On the east side of this tower, and built up against it, is a small rounded platform 3 feet high, covered with granite cement, which is approached by two large steps.

*Entrances.*—There are three entrances to these ruins—the north, north-east, and east—but most probably others will be found as further exploration work is carried out here. The north entrance appears to have been the main approach. This is an intricate entrance, and one which appears to have possessed considerable importance in the minds of the original builders. It lies between two outer curved walls, which round off towards each other in the form of a trumpet. These curve inwards so as to form a passage way 6 feet wide, which at 10 feet further south is narrowed to 2 feet 6 inches by two rounded buttresses, one on either side, and these have portcullis grooves. The entrance opens into a walled-in area, 10 feet by 10 feet, the walls being 6 feet high and very well and substantially built. There are three rounded walls in this area, and the floor is made of granite cement. A buttress with portcullis grooves is on the south-western corner of this area, but the corresponding buttress has disappeared. The walled-in area would have enabled twenty defenders to protect the 2 feet 6 inches wide entrance from being forced by an attacking party, even if strong in point of numbers. The eastern side of this entrance is carried on for 15 feet further south by two walls, each built upon a semi-circular plan.

The north-west entrance opens directly into the enclosure which contains the conical tower just described. The side walls are now only 5 feet in height and 4 feet to 6 feet wide at this height from the floor. The entrance is 2 feet 6 inches wide, and including the steps, is 9 feet long. A semi-circular platform projects 6 feet into the enclosure, and on it are built rounded buttresses, with portcullis grooves. These buttresses are in an advanced stage of dilapidation. There are three steps between the buttresses.

At present only the south side of the east entrance has been opened out. This is 4 feet high, and is rounded. On the inner side is a semi-circular buttress, hollow inside, with a rounded entrance on the south side.

All the entrances in divisional walls, of which there are eleven, are rounded, and most have portcullis grooves.

At the centre of the eastern face of the massive curved wall is a rounded entrance with portcullis groove, into which is built a slate beam lintel, which stands 8 feet above the floor. The total length of this beam is at least 11 feet. This is the most perfect of all the stone lintels built in portcullis grooves.

*Enclosures.*—Judging by sections of divisional walls, there were in all probability no less than sixteen enclosures in these ruins. Some were of large area, but sub-divided. All the divisional walls were built on curved plan.

The only complete enclosure is the one on the north side of the ruins, where stands the conical tower. The wall on the south side is from 5 feet to 9 feet high, on the west side 5 feet to 10 feet, and on the north side, which is an outer wall, 5 feet high, and the reduced summit 4 feet wide at 5 feet from the floor.

*Buttresses.*—A prominent feature in these ruins is the large number of large semi-circular buttresses. One buttress is 5 feet high, 22 feet round the face, 9 feet from back to front, and 12 feet across the back; it faces the west, and also the centre of the east face of the curved wall at 25 feet distance. The floor of the passage surrounding this buttress is laid with thick granite cement, on which are large rounded cement steps.

*Drains.*—So far as these ruins have been cleared out of débris, there have only been two walls discovered here. They are both at the northern end of the ruins; one passes through the outer wall, 6 feet wide, and the other through a divisional wall, 5 feet wide, which runs parallel with the eastern face of the curved wall.

*Cement.*—Granite cement has been most extensively employed for flooring, dados, covering of steps, and for raised platforms in the angles of walls, which somewhat resemble the "blind steps" found in all the main ruins of Zimbabwe.

## REPORT OF THE COUNCIL FOR THE PERIOD ENDED

MAY 2ND, 1903.

Although the First Annual Meeting of the South African Association for the Advancement of Science did not take place until April 27th, 1903, the question of the formation of an Association of this nature had been receiving attention for more than two years previous to that date. The first practical step was taken on the 4th March, 1901, when a meeting was arranged in Cape Town by Mr. T. Reunert and other Johannesburg and Cape Town engineers. At this meeting it was decided to ascertain the opinion of engineers throughout South Africa as to the advisability of holding an annual congress of members of that profession.

The further account of the early development of the Association will be found in the President's Address.

The members of the first Council of the South African Association for the Advancement of Science were elected at a meeting of the General Committee held in Cape Town on the 20th January, 1902. The election was by ballot, consideration being given to the nominations received from members in the various parts of South Africa in which the Association was represented.

The President, Vice-Presidents, General Secretaries, Treasurer, and Assistant General Secretary were elected by the Council at a meeting held on the 27th January, and the Managing Committee of Council was also appointed at this meeting. Since that date two members of Council have resigned, namely, Mr. A. W. Ackermann and Dr. G. S. Corstorphine. In order that vacancies similarly arising in the intervals between the Annual Meetings, at which the Council is elected, might be filled up without delay, the following bye-law was passed by the Council, viz.: "That in the event of any vacancy occurring from any cause in the membership of the Council, the Council shall have power to fill such vacancy or vacancies." Mr. W. L. Sclater and Professor J. C. Beattie were thereupon elected to fill the vacancies.

On the 24th May, 1902, the inaugural meeting of members of the Association resident in Johannesburg took place, and a strong local committee was formed there.

Owing to the increase in the membership of the Association, and to the rapid extension of its sphere of influence, it was found necessary, in order to cope with the additional work involved, to divide the secretarial work; that in connection with the Transvaal, the Orange River Colony, and Natal being directed from Johannesburg; while the officers at Cape Town are responsible for the affairs of the Association in Cape Colony, Rhodesia, and other parts of South Africa.

On account of the very unsettled state of the country, consequent upon the war, it was found impossible to hold a meeting during

the year 1902. After peace had been restored, however, the opportunity was taken of arranging for the First Session, and on the 13th June, 1902, it was decided that this should take place in Cape Town during the Easter holidays of 1903. On the 20th June a local committee was formed to assist in carrying out the arrangements, but it was found that the lecture theatres at the South African College, which had been kindly promised for the occasion, would not be available at Easter, and as no other suitable quarters were procurable, it was decided that the Session should be from the 27th April to the 2nd May. The Sectional Committees were appointed at a joint meeting of the Council and the Local Committee held on the 1st August, 1902, and on the 12th September the members of the Reception, Entertainments and Excursions Committees were elected.

The Local Committee of the Association at Johannesburg having moved in the direction of securing the establishment of a Meteorological Department in the Transvaal, the Council co-operated in pressing the matter on the attention of the Transvaal Government. The Government kindly consented to the petition, and it is anticipated that much useful work will be the result.

On May 2, 1903, the closing day of the First Session, the number of members, including 41 associate members, stood at 765. The list includes members from all the principal centres in Cape Colony, the Transvaal, the Orange River Colony, Natal, and Rhodesia; British Central Africa and German South-West Africa being also represented.

As the financial year of the Association does not end until the 30th June, all those who joined the Association on or before that date in the present year, and who have paid their subscriptions, will be entitled to a copy of this Report. The list of members printed in the Report and the Treasurer's statement will be completed up to the 30th June, 1903. It will thus be seen that those who joined the Association on or before the 30th June, 1902, will have paid subscriptions for two years, whereas they have only received the same benefits as those who became members subsequent to that date. To these members, who number 268, the Association is undoubtedly much indebted, as it was only with their generous support that it was possible to carry on the initial work of the Association. It has been decided that these members shall rank as "Foundation Members," and their names will be specially denoted in the list.

At the General Meeting held at the termination of the Session it was unanimously decided to convey the thanks of the Association:—

To the Government of the Colony of the Cape of Good Hope, for the great aid they have rendered this Association and its work, especially in providing funds for the printing of this Report.

To Rear Admiral Sir A. W. Moore, K.C.B., for his kind reception of the Members of the Association.

To Sir David and Lady Gill, for their kind hospitality to the Members of the Association.

To the Mayor and Corporation of Cape Town, for their liberal hospitality to the Association.

To the Council of the South African College, to the Trustees of the Museum and Art Gallery, and to the Superintendent-General of Education, for the use of their rooms, so generously placed at the disposal of the Council of the Association.

To the Agricultural Department, the South African Philosophical Society, the Management of the De Beers Explosives Works, Mr. and Mrs. H. M. Arderne, the Cape Town Clubs, and the Chamber of Commerce, the Trustees of Groote Schuur Estate, and to all who contributed to the entertainment of the visitors.

To the various Railway administrations of South Africa, for travelling facilities granted to Members of the Association.

To the Management of the Union-Castle Mail Steamship Company, for the travelling facilities granted to Members of the Association.

To the Press, for its sympathetic attitude towards the Association since its inception, and for the excellent manner in which they reported the proceedings of this meeting.

To the various Governments of South Africa for the substantial financial aid which they have promised in connection with the proposed visit of the British Association to South Africa in 1905.

The following is an epitome of the programme of the first Session:—

**MONDAY, APRIL 27TH.**

3 p.m.—Meeting of Council at the Education Hall, Church-square.

8 p.m.—The President's Address at the Public Library.

**TUESDAY, APRIL 28TH.**

10 a.m.—Committees of Sections meet.

10.30 a.m.—Meetings of Sections.

2.15 p.m.—Meetings of Sections.

4 p.m.—Reception at the Royal Observatory by invitation of Sir David and Lady Gill.

8 p.m.—Lecture at the South African College, by Professor W. S. Logeman, I.H.C., B.A. Subject: "The Ruins of Persepolis and how the Inscriptions were read."

**WEDNESDAY, APRIL 29TH.**

9.15 a.m.—Meeting of Council.

10 a.m.—Committees of Sections meet.

10.30 a.m.—Meetings of Sections.

2.15 p.m.—Meetings of Sections.

4 p.m.—Visit to Mr. Arderne's garden at Claremont.

8 p.m.—Reception and Conversazione in the South African Museum, by invitation of the Mayor and Mayoress of Cape Town (Mr. and Mrs. W. Thorne).

THURSDAY, APRIL 30TH.

- 9 a.m.—Visit to the De Beers Explosives Works at Somerset West.
- 8 p.m.—Reception by the Philosophical Society in the Oak Hall, Young Men's Christian Association, Long-street.

FRIDAY, MAY 1ST.

- 7 a.m.—Ascent of Table Mountain.
- 9.30 a.m.—Drive round the Mountain, *via* Hout Bay and Wynberg.
- 2.35 p.m.—Visit to Government Wine Farm, Groot Constantia.
- 8 p.m.—Royal Observatory open to Members and Associates.

SATURDAY, MAY 2ND.

- 8.30 a.m.—Meeting of Council.
  - 9 a.m.—General Meeting of Members at the Education Hall, Church-square, for the purpose of electing the new Council and for General Business.
  - 10.35 a.m.—Visit to Simon's Town, and subsequently to the Marine Biological Station, St. James's, and Groote Schuur.
  - 8 p.m.—Royal Observatory open to Members and Associates.
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REPORT BY THE HON. TREASURER FOR THE TWO  
YEARS 1901-02 AND 1902-03.

It had been the desire of the Hon. Treasurer to present a complete financial statement of the Association's affairs for the whole of South Africa, but he has been unable for various reasons to obtain the necessary data from the Johannesburg Branch, and a separate statement is attached dealing with the affairs of that Branch.

From this it would appear that there were 69 members for the year 1901-02 and 336 members for 1902-03, and in addition 3 life members.

The unpaid subscriptions are given as £13 for the first year and £76 10s. for the second year; total, £89 10s.

The expenditure is £229 14s. 10d., and this is covered by vouchers, which were examined and certified as correct by Mr. Pym the auditor.

As, however, the figures given of the membership do not tally with our records here, the Hon. Treasurer has thought it advisable not to incorporate the statement submitted with that for the Cape Colony and Rhodesia, but to print it as it stands and endeavour to obtain the final and correct number during the current year, and present a complete statement at the termination thereof in connection with the next annual report.

As regards the membership for Cape Colony and Rhodesia, it has now been finally settled that this amounts to 211 (which includes 2 life members) for the year 1901-02, and all these members are to be considered foundation members.

For the year 1902-03 the membership was 408, of which 5 were life members.

The associates for the year number 39.

With regard to the unsatisfactory fact of so many subscriptions being still outstanding for 1901-02, the Hon. Treasurer would suggest that a definite term be set for the payment of these, and that on expiry of such term the names of the defaulters be struck off the list of membership.

In most cases four reminders have been sent to members in arrears without eliciting any reply.

W. WESTHOFEN,

Hon. Treasurer

SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.  
FINANCIAL STATEMENT FOR THE TWO YEARS ENDED 30TH JUNE, 1903.

CAPE COLONY AND RHODESIA.

REPORT OF THE TREASURER.

521

		£	s.	d.		£	s.	d.	
1901-02	By Subscriptions from 2 Life Members ...	20	0	0	1901-02 and 1902-03	By Expenditure for Printing, Stationery, Books, Salaries, Petty-Cash, Stamps and Telegrams, as per Cash Book and Vouchers ...	36	14	9
"	" " Members...	171	18	0		" Subscriptions unpaid : -			
1902-03	" " 3 Life Members ...	30	0	0		1901-02 Members	33	10	0
"	" " Members...	288	16	0		1902-03 "	116	0	0
"	" " Associates	26	5	0		" Associates	3	0	0
"	" Contribution on a/c by Johannesburg Branch ...	100	0	0		" Balance in Bank on 30th June, 1903 ...	276	4	3
"	" Subscriptions from Members remaining unpaid for 1901-02 ...	33	10	0					
"	" Subscriptions from Members remaining unpaid for 1902-03 ...	116	0	0					
"	" Subscriptions from Associates remaining unpaid for 1902-03 ...	3	0	0					
		£789	9	0					

L.L.

## SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

(TRANSVAAL, ORANGE RIVER COLONY, AND NATAL SECTIONS.)

## Balance Sheet for period from formation of Association to 30th June, 1903.

To Due to the Association for Subscriptions :—		By Subscriptions received at Cape Town and handed over prior to 1st February, 1902	
60 Members at £2 ...	£138 0 0	...	£24 0 0
267 " at £1 ...	267 0 0	Subscriptions of transferred Members paid at Cape Town and unrecoverable owing to death, etc.	19 0 0
	— £405 0 0		£43 0 0
" Subscriptions prepaid ...	...	Expenditure covered by receipts or vouchers as per audited Cash Book	229 14 10
" " from Life Members	... 30 0 0		...
" Incidental receipts ...	0 14 0	Subscriptions unpaid at 30th June, 1903—	
" Conversazione ...	29 8 0	64 at £2 ...	13 0 0
" Tree Planting Lecture receipts ...	4 10 0	764 at £1 ...	76 10 0
			89 10 0
		Balance as follows :—	
	34 12 0	Cash remitted to Cape Town, 21st April, 1903 ...	160 0 0
		Cash in hand, 30th June, 1903	11 7 2
			111 7 2
			<u>£473 12 0</u>
			<u>£473 12 0</u>

LIST OF MEMBERS OF THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, UP TO JUNE 30TH, 1903.

° Indicates Life Members.

\* Indicates Foundation Members, *i.e.*, those who were members of the Association on June 30th, 1902.

*Members are requested to notify the Secretary of any corrections that may be needed in the list.*

- °Ababrelton, Robert A., F.R.C.I., P.O. Box 242, Pietermaritzburg, Natal.
- \*Aburrow, C., P.O. Box 534, Johannesburg.
- \*Ackermann, A. W., Assoc.M.Inst.C.E., M.S.I., M.C.M.E., P.O. Box 426, Cape Town.
- \*Ackermann, Mrs. A. W., c/o A. W. Ackermann, Esq., P.O. Box 426, Cape Town.
- \*Ackermann, Miss Kate, c/o A. W. Ackermann, Esq., P.O. Box 426, Cape Town.
- \*Adams, Ernest Victor, Whyteleafe, H.M. Dockyard Extension, Simon's Town, Cape Colony.
- \*Adamson, William, P.O. Box 426, Cape Town.
- Agutter, Thomas Charles, Architect and C.E., R. Naval Yard, Simon's Town, Cape Colony.
- Ainslee, George, 3, Kathleen Villas, Observatory Road, near Cape Town.
- Ainsworth, Herbert, P.O. Box 1553, Johannesburg.
- Albrecht, John August, Assoc.M.I.Mech.E., P.O. Box 1361, Cape Town.
- Amphlett, George Thomas. Standard Bank of South Africa, Ltd., Cape Town.
- Anderson, Alfred Jasper, M.A., M.B. Oxon., D.P.H. Camb., M.R.C.S. Lond., 4, Church Square, Cape Town.
- Anderson, W. T., P.O. Box 184, Germiston, Transvaal.
- \*Andrews, G. S. Burt, Assoc.M.Inst.C.E., M.S.A., P.O. Box 1049, Johannesburg.
- Armstrong, A. C., c/o Milliken Bros., Engineers, P.O. Box 388, Cape Town.
- Armstrong, W., c/o Armstrong & Co., Port Elizabeth, Cape Colony.
- Arnold, Dr. F., P.O. Box 2, Middelburg, Transvaal.
- Arnott, William, Gas Works, Port Elizabeth, Cape Colony.
- \*Attridge, Ernest William, C.E., F.I.San.E., Mount Pleasant, Simon's Town, Cape Colony.
- Auret, A. A., P.O. Box 838, Johannesburg.
- Austin, Henry B., Government Deeds Office, Bloemfontein.
- Ayres, G. F., Woodward, Rondebosch, near Cape Town.

- Babbs, Arthur Thomas, Member Quantity Surveyors' Association, England, Rhodes Buildings, Cape Town.
- Badcock, F. D., Assoc.M.Inst.C.E., M.A., Town Engineer, Pretoria.
- Bailey, Dr. W. F., Falmouth Villa, Main Road, Sea Point, near Cape Town.
- \*Baker, Herbert, F.R.I.B.A., Standard Bank Buildings, Johannesburg.
- Ball, Thos. J., P.O. Box 2536, Johannesburg.
- Balmforth, Rev. Ramsden, Daisy Bank, Upper Camp Street, Cape Town.
- \*Banham, Charles Proctor, M.Inst.E.E., M.I.Mech.E., Table Bay Harbour Works, Cape Town.
- Banks, John, Rietfontein "A" G.M. Co., Johannesburg.
- \*Barker, J. R. K., Queen's Town, Cape Colony.
- \*Barnes, J. F. E., C.M.G., Public Works Department, Maritzburg, Natal.
- Baxter, William, M.A., South African College School, Cape Town.
- \*Bays, F. E., M.D. Lond., Graham's Town, Cape Colony.
- \*Beattie, Professor J. C., D.Sc., F.R.S.E., South African College, Cape Town.
- Beck, Dr. J. H. Meiring, The Drostdy, Tulbagh.
- \*Becker, Hermann Franz, M.D., F.L.S., F.S.A., Die Duvencok, Graham's Town, Cape Colony.
- Beckett, G. Wm., P.O. Box 424, Pretoria.
- Beckmann, A. Eckart, P.O. Box 417, Johannesburg.
- \*Behr, H. C., P.O. Box 67, Johannesburg.
- \*Beisly, P. S., P.O. Box 50, Germiston, Transvaal.
- Bell, H. T. M., B.A., P.O. Box 4832, Johannesburg.
- Bell, W. Reid, M.Inst.C.E., F.R.Met.Soc., M.I.E.S., P.O. Box 78, Potchefstroom, Transvaal.
- Bender, Rev. A. P., M.A., Synagogue House, Cape Town.
- Benington, C. E., P.O. Box 825, Pretoria.
- Bennett, A. C., M.D., Griqualand, Dist. Hay, Cape Colony.
- \*Bennett, Thomas, M.Inst.C.E., Municipal Offices, Muizenberg, near Cape Town.
- Benson, Mrs. W. J., Standard Bank, Johannesburg.
- Bernfeld, G., P.O. Box 3072, Johannesburg.
- \*Berry, Hon. Sir William Bisset, Kt., M.A., M.D., M.L.A., Queen's Town, Cape Colony.
- Beyers, Advocate, P.O. Box 1115, Johannesburg.
- Beynon, J. C. S., Assoc.M.Inst.C.E., P.O. Box 2926, Johannesburg.
- Biden, Arthur, P.O. Box 3384, Johannesburg.
- Bidwell, C. Hugh, P.O. Box 24, Bloemfontein.
- Bisset, James, J.P., M.Inst.C.E., Beauliegh, Kenilworth, near Cape Town.
- Blaine, H. F., Bloemfontein.
- Blaker, William Herbert, Asst. Engineer to Sir John Jackson, Ltd., Admiralty Harbour Works, Simon's Town, Cape Colony.
- \*Blane, Jas., P.O. Box 101, Germiston, Transvaal.
- Bliden, Dr., P.O. Box 5297, Johannesburg.
- Blore, Harold W. J., P.O. Box 31, Johannesburg.

- Bloxam, Hugh Charles London. Analyst and Laboratory Manager, Heynes, Mathew & Co., Cape Town.
- Bolus, Harry, D.Sc., F.L.S., Sherwood, Kenilworth, near Cape Town.
- \*Boulton, H. C., Rhodesia Railways, Box 153, Salisbury, Rhodesia.
- Bradley, A. A., P.O. Box 5, Cleveland, Johannesburg.
- \*Brain, H. A., H.M. Naval Yard, Simon's Town, Cape Colony.
- \*Braine, Charles Dimond Horatio, Assoc.M.Inst.C.E., Drainage Works, Town Hall, Mowbray, near Cape Town.
- Brakhan, A., P.O. Box 4249, Johannesburg.
- Brearley, Frederick Thomas, M.I.Mech.E., Assoc.M.Inst.C.E., Pendennis, Muizenberg, near Cape Town.
- Brearley, Mrs. F. T., Pendennis, Muizenberg, near Cape Town.
- Brennan, Francis Joseph, Architect, c/o Brennan & Hill, P.O. Box 16, Kimberley, Cape Colony.
- Brice, Seward, M.A., LL.D., K.C., Rand Club, Johannesburg.
- \*Brigham, Alexander Fay, Mining Engineer, De Beers Consd. Mines, Ltd., Kimberley, Cape Colony.
- Brims, Charles R., C.E., New Dock Works, Simon's Town, Cape Colony.
- \*Bromley, Robert, C.E., District Inspector No. 1 District, Public Works Department, Cape Town.
- \*Brooks, Edwin James Dewdney, C.E., West Bank, King William's Town, Cape Colony.
- \*Brooks, F. C., P.O., Box 56, Zeerust, Transvaal.
- Broom, Robert, M.D., C.M., B.Sc., C.M.Z.S., Pearston, Cape Colony.
- Brown, Professor Alexander, M.A., B.Sc., South African College, Cape Town.
- Brown, Alex. F., P.O. Box 342, Johannesburg.
- Brown, A. J. Studd, P.O. Box 2697, Johannesburg.
- \*Brown, John, C.M.G., M.Inst.C.E., Engineer-in-Chief, Cape Government Railways, Cape Town.
- Brown, Dr. Johnstone, M.B., C.M., P.O. Box 94, Jeppestown, Johannesburg.
- Brown, W. M., Transvaal Estates and Development Co., Johannesburg.
- Brown, William Nimmo, District Forest Officer, Uitvlucht, Mowbray, near Cape Town.
- Browne, Rev. Langford Sotheby, Trin. Coll. Dublin, Mellington, Kenilworth, near Cape Town.
- Browne, Revd. W. G., 8, Mortgage Buildings, Pretoria.
- \*Buchan, James, P.O. Box 48, Mafeking, Cape Colony.
- Buck, E. C., P.O. Box 440, Pretoria.
- Buckland, J. M., Rand Club, Johannesburg.
- Byden, A. J., Rhodes Buildings, Cape Town.
- \*Cairncross, T. W., Colonnade Buildings, Greenmarket Square, Cape Town.
- Caldecott, W. A., B.A., F.C.S., P.O. Box 67, Johannesburg.

- \*Callen, Thomas. Assoc.M.Inst.C.E., M.S.I., Borough Engineer, Kimberley, Cape Colony.
- Camerer, R., P.O. Box 2358, Johannesburg.
- \*Campbell, Allan McDowell McLeod, C.E., B.A., F.I.Inst., Resident Engineer, Aliwal North, Cape Colony.
- Carper, J. B., P.O. Box 149, Johannesburg.
- Carter, Mrs. W. J. Becher, Alexandra Club, Burg Street, Cape Town.
- Cartwright, Albert, P.O. Box 686, Cape Town.
- Cartwright, Mrs. Albert, c/o Albert Cartwright, Esq., P.O. Box 686, Cape Town.
- Cartwright, John Dean, M.I.A., Beau Soleil, Salisbury Road, Wynberg, near Cape Town.
- Cartwright, Mrs. J. D., Beau Soleil, Salisbury Road, Wynberg, near Cape Town.
- Cashmore, M., M.P.S., P.O. Box 3320, Johannesburg.
- \*Catlin, R.M., B.Sc., C.E., E.M., P.O. Box 21, Germiston, Transvaal.
- Cazalet, Percy, M.S.A.A.E., P.O. Box 1056, Johannesburg.
- Chabaud, John Anthony, Attorney-at-Law, Wyndomayne, Park Drive, Port Elizabeth, Cape Colony.
- \*Chapman, Arthur Dodwell, Assoc.M.Inst.C.E., District Engineer, Cape Government Railways, Port Elizabeth, Cape Colony.
- \*Charlton-Perkins, W. T., P.O. Houw Hoek, Caledon, Cape Colony.
- Child, Harry Shaw, M.I.Mech.E., Uitenhage, Cape Colony.
- Chute, Henry Macready, M.R.C.S., L.R.C.P.Edin., Ayliff Street, King William's Town, Cape Colony.
- Cinnamon, Isaac, P.O. Box 7, Pretoria.
- Clark, John, M.A., LL.D., Professor of English Language and Literature, South African College, Cape Town.
- \*Clarke, Alfred A., P.O. Box 92, Johannesburg.
- \*Clarke, Revd. W. E. C., M.A., P.O. Box 1144, Pretoria.
- Clarkson, R., Rietfontein "A," Johannesburg.
- \*Clarkson, W. J., P.O. Box 4660, Johannesburg.
- \*Cleeve-Edwards, Walter, Assoc.M.Inst.C.E., M.I.Mech.E., F.G.S., Public Works Department, Port Elizabeth, Cape Colony.
- Clementson, Rev. William Lawson, M.A.Cape, B.D.Durham, S. Mark's Rectory, Cape Town.
- Cliffe, F., New Club, Johannesburg.
- \*Cobley, W. H., M.Inst.C.E., I.S.O., Govt. Rlys., Pietermaritzburg, Natal.
- \*Cochrane, Louis H., District Engineer, Cape Government Railways, Cape Town.
- Cohen, W. P., P.O. Box 68, Johannesburg.
- Colenbrander, W. M., Government Land Surveyor, Cape University, P.O. Box 14, Vryheid, Transvaal.
- \*Colley, John, M.I.Mech.E., Certificated Colliery Manager, Indwe Mines, Cape Colony.
- \*Collie, James V. B., F.I.S.E., R.P.C., 15, Barrack Street, Cape Town.
- Colls, A. Stanley, Public Works Department, Pretoria.

- \*Colson, William Henry, C.E., Queen's Road, Simon's Town, Cape Colony.
- \*Connolly, R. M., P.O. Box 862, Johannesburg.
- Cook, Arthur, The Foreland, Avenue Protea, Sea Point, near Cape Town.
- Cook, Mrs. Arthur, The Foreland, Avenue Protea, Sea Point, near Cape Town.
- Cook, John, Town House, Cape Town.
- Cooke, Herbert S., M.A. Oxon., P.O. Box 1086, Pretoria.
- Corbalis, Captain James, Talana, Plumstead, near Cape Town.
- \*Corner, Charles, Assoc.M.Inst.C.E., Assoc.M.Am.Soc.C.E., District Engineer, Rhodesia Railways, Gwelo, Rhodesia.
- \*Corstorphine, George Steuart, B.Sc.Edin., Ph.D.München, P.O. Box 1167, Johannesburg.
- \*Cory, Professor George Edward, M.A., S. Andrew's College, Graham's Town, Cape Colony.
- \*Coster, William Wallace, Assoc.M.I.Mech.E., 67B, Long Street, Cape Town.
- Couper, Lindley Clyde, Equitable Life Assurance Society, P.O. Box 250, Cape Town.
- Covernton, R. H., M.Inst.E.E., Assoc.M.Inst.C.E., P.O. Box 1049, Johannesburg.
- Cox, Douglas Brenton, Natal Government Railways, Maritzburg, Natal.
- \*Cox, Walter Hubert, Royal Observatory, near Cape Town.
- \*Craig, J., District Engineer, Queen's Town, Cape Colony.
- \*Craig, William, Assoc.M.Inst.C.E., Public Works Department, Cape Town.
- \*Crawford, Professor Lawrence, M.A., D.Sc., F.R.S.E., South African College, Cape Town.
- Creswell, F. H. P., A.M.S.M., Assoc.M.Inst.C.E., A.I.M.M., P.O. Box 1091, Johannesburg.
- \*Cross, Revd. G. W., Baptist Parsonage, Pretoria.
- Crosse, Andrew F., P.O. Box 22, East Rand, Transvaal.
- Crowder, Thos. Herbert, Natal Government Railways, Maritzburg, Natal.
- Cullen, William, Dynamite Factory, Modderfontein, Transvaal.
- Curnow, Robert, P.O. Box 352, Krugersdorp, Transvaal.
- Currie, Dr. O. J., M.B. Lond., M.R.C.S.Eng., 18, Longmarket Street, Maritzburg, Natal.
- \*Dale, J. W., C.E., Beaconsfield, Cape Colony.
- Dalrymple, W., P.O. Box 2927, Johannesburg.
- Darling, Geo. A., P.O. Box 1024, Johannesburg.
- \*Darroll, George, 16, Hout Street, Cape Town.
- Davis, Fred. H., B.Sc., M.E.E.E., P.O. Box 1934, Johannesburg.
- Davis, J. Hubert, M.Inst.E.E., M.I.Mech.E., Assoc.M.Inst.C.E., P.O. Box 1386, Johannesburg.
- Davy, J. B., F.L.S., F.R.G.S., Fel.Amer.A.A.S., Government Agrostologist and Botanist, Department of Agriculture, Pretoria.

- Dendy, Professor Arthur, D.Sc., F.L.S., South African College, Cape Town.
- \*Denham, John, M.Inst.E.E., M.I.Mech.E., M.Amer.Inst.E.E., Electrical Engineer, Cape Government Railways, Cape Town.
- \*Denny, G. A., M.Amer.Inst.M.E., F.M.Aus.Inst.M.E., M.N.Z.Inst.M. & M.E., M.Inst.M.M., F.S.A., M.S.A.A.E., P.O. Box 4181, Johannesburg.
- \*Denny, H. S., S.M.B., M.S.A.A.E., P.O. Box 4181, Johannesburg.
- De Pinna, Harry, A.Inst.E.E., Courtis Chambers, St. George's Street, Cape Town.
- De Roos, John L., P.O. Box 75, Johannesburg.
- De Witt, Anthony M., Architect, Colonnade Buildings, Greenmarket Square, Cape Town.
- De Witt, Mrs. Anthony M., c/o Anthony M. de Witt, Esq., Colonnade Buildings, Greenmarket Square, Cape Town.
- \*Dickens, A., Graham's Town, Cape Colony.
- Dickinson, Harold E., P.O. Box 155, Johannesburg.
- Dobson, W. H., A.San.I., Health Board, Standerton, Transvaal.
- Dodds, William John, M.D., Valkenberg, Mowbray, near Cape Town.
- Dominicus, L., Saving's Bank Buildings, St. George's Street, Cape Town.
- Donelly, C. O'Connor, P.O. Box 3142, Johannesburg.
- \*Douglass, Hon. Arthur, M.L.A., Buana Vista, Wynberg, near Cape Town.
- \*Drake, Francis, M.Amer.I.Mech.E., P.O. Box 3258, Johannesburg.
- Drake, Francis Bragg, Assoc.M.Inst.C.E., Town Engineer & Surveyor, Mowbray Municipality, Town Hall, Mowbray, near Cape Town.
- \*Dru-Drury, Dr. E., Graham's Town, Cape Colony.
- Dubois, Raymond, Ingénieur Agricole, B.Sc., F.C.S., Department of Agriculture, Cape Town.
- Duft, Gustav, Kaiserlicher Bergrath, Windhoek, German S.W.Africa, *via* Swakopmund.
- Dumat, Frank C., F.R.A.S., P.O. Box 370, Johannesburg.
- Duncan, James, P.O. Box 1450, Johannesburg.
- \*Dunn, G. H., c/o G. Findlay & Co., Cape Town.
- \*du Preez, D., School of Mines, Kimberley, Cape Colony.
- \*du Preez, M., School of Mines, Kimberley, Cape Colony.
- \*Dyer, Bertram L., Hon.M.L.A.A., Public Library, Kimberley, Cape Colony.
- Easton, Miss Florence, Charlton House, Mowbray, near Cape Town.
- Edgar, Professor John, M.A., South African College, Cape Town.
- \*Edington, Alexander, M.D., F.R.S.E., Director of the Colonial Bacteriological Institute, Graham's Town, Cape Colony.
- \*Edmondson, Cressy S., P.O. Box 5107, Johannesburg.
- \*Edwards, A. J., Municipal Engineer, Wynberg, near Cape Town.
- Edwards, H. A. Bidewell, 80, St. George's Street, Cape Town.

- Elder, George Irwin. Uitvlugt Forest. Mowbray, near Cape Town.  
 Ensor, E. E., P.O. Box 302, Pretoria.  
 Epler, A., P.O. Box 907, Johannesburg.  
 Epton, W. Martin, Assoc.M.I.Mech.E., Mines Dept., Johannesburg.  
 Espinasse, James, B.A., B.A.I., T.C.D., Assoc.M.Inst.C.E.,  
 Engineer's Office, Indwe-Maclear Railway, Indwe, Cape Colony.  
 Evans, David C., P.O. Box 1020, Johannesburg.  
 Evans, Harry, A.P.S., c/o P. J. Petersen & Co., P.O. Box 38, Cape  
 Town.  
 Evans, J. Emrys, P.O. Box 1126, Johannesburg.  
 Evans, Lewis, New Modderfontein, Benoni, Transvaal.  
 Exham, Horace William, B.A.Cape, Education Office, Cape Town.  
 Exton, Dr. H., Port Alfred, Cape Colony.
- Feitelberg, Samuel, Fairview, Main Road, Green Point, near Cape  
 Town.  
 Felgate, J., M.S.I., P.O. Box 569, Johannesburg.  
 Fergusson, Malcolm, A.R.S.M., F.R.G.S., P.O. Box 691, Johannes-  
 burg.
- \*Field, A., 44, Adderley Street, Cape Town.  
 Fisher, J. S., Inspector of Mines Office, Johannesburg.  
 \*Fitt, J. Edward, Assoc.M.Inst.C.E., c/o Cochrane & Fitt, Maitland,  
 Cape Colony.  
 Fitz-Henry, Rev. J., Naauwpoort, Cape Colony.  
 Fitz-Patrick, Sir J. Percy, M.L.C., P.O. Box 149, Johannesburg.  
 \*Flack, Rev. Francis Walter, M.A., R.D., S. Paul's Rectory, Port  
 Elizabeth, Cape Colony.  
 Flanagan, Henry George, F.L.S., Prospect Fram, Komgha, Cape  
 Colony.
- \*Fletcher, J., Town Engineer, Durban, Natal.  
 \*Fletcher, R. W., P.O. Box 92, Johannesburg.  
 \*Flint, Rev. William, D.D., Wolmunster Park, Rosebank, near Cape  
 Town.  
 \*Flowers, Frank, C.E., F.R.G.S., P.O. Box 1952, Johannesburg.  
 Flowers, Harry, Bruce Cottage, Main Road, Green Point, near Cape  
 Town.  
 Flowers, W. W., P.O. Box 4678, Johannesburg.
- \*Ford, James, 7, De Lorentz Street, Cape Town.  
 Ford, S. H., A.R.S.M., M.I.Mech.E., P.O. Box 550, Johannesburg.  
 Forster, John Douglas, Rand Club, Johannesburg.  
 \*Foster, A. J., Public Works Department, Graham's Town, Cape  
 Colony.  
 Fox, Geo. C., P.O. Box 1961, Johannesburg.  
 Frames, Charles, Port Elizabeth, Cape Colony.  
 Frames, Minett E., F.G.S., P.O. Box 8, Johannesburg.  
 Franks, Kendal, C.B., M.A., M.B., M.D., Member of the Senate &  
 Ex Sch. Univ. Dublin, P.O. Box 1858, Johannesburg.  
 Fraser, J. C., c/o Stephen Fraser & Co., Port Elizabeth, Cape  
 Colony.  
 Fremantle, Henry Eardley Stephen, M.A., F.S.S., Bedwell Cottage,  
 Rosebank, near Cape Town.

- Frerichs, J. A., P.O. Box 67, Johannesburg.  
 Fricker, Robert G., P.O. Box 498, Johannesburg.  
 Frost, W. T. Hyde, P.O. Box 306, Johannesburg.  
 Frost, Mrs. W. T. H., P.O. Box 306, Johannesburg.  
 \*Fuhr, Harry Augustus, Assoc.M.Inst.C.E., Public Works Department, King William's Town, Cape Colony.  
 Fuller, Edward Barnard, M.B., C.M., F.R.C.S., J.P., Hawthornden, Rosmead Avenue, Cape Town.
- \*Galpin, Alfred Carter, P.O. Box 14, Graham's Town, Cape Colony.  
 Galpin, Ernest Edward, F.L.S., c/o The Bank of Africa, Ltd., Queen's Town, Cape Colony.  
 Gardthausen, C. G., P.O. Box 80, Pretoria.  
 \*Gartzweiler, L., P.O. Box 92, Johannesburg.  
 \*Gasson, W., Chemist, Du Toitspan Road, Kimberley, Cape Colony.  
 Gazzam, Joseph P., P.O. Box 192, Germiston, Transvaal.  
 \*Gibbons, William Clark, Relief Works, Parys, Orange River Colony.  
 \*Gibbons, W. F., Cape Lime Co., 34, Burg Street, Cape Town.  
 Gibson, Harry, J.P., 133, Longmarket Street, Cape Town.  
 \*Gilchrist, J. D. F., M.A., Ph.D., B.Sc., Department of Agriculture, Cape Town.  
 Gilchrist, Wm., M.S.A., P.O. Box 401, Johannesburg.  
 Gilfillan, W. H., Assistant Surveyor General, Pretoria.  
 \*Gill, Sir David, K.C.B., LL.D., F.R.S., Hon. F.R.S.E., Royal Observatory, near Cape Town.  
 Gill, Professor James, M.A. Camb., Muizenberg, near Cape Town.  
 \*Gillespie, John, Resident Engineer, Norval's Pont, Dist. Colesberg, Cape Colony.  
 Gilmour, David, Assoc.M.Inst.C.E., P.O. Box 231, Johannesburg.  
 Gird, Harry, Prospect Farm, Klipheuvall, Malmesbury, Cape Colony.  
 Gird, W., Middlepost, Klipheuvall, Malmesbury, Cape Colony.  
 Goatcher, Alfred Winton, Royal Observatory, near Cape Town.  
 \*Godfrey, A. G., Grand Junction Railways, Cookhouse, Cape Colony.  
 \*Godfrey, J. J., Buffalo Bridge Offices, East London, Cape Colony.  
 Godfrey, Revd. J. R., P.O. Box 815, Pretoria.  
 Goldmann, Richard, P.O. Box 2424, Johannesburg.  
 Gomoszynski, Casimir T., 3, Rheede Street, Cape Town.  
 Good, Harry, Assoc.M.Inst.C.E., F.R.G.S., P.O. Box 1049, Johannesburg.  
 \*Good, Montagu, P.O. Box 20, Salisbury, Rhodesia.  
 Goodwin, Geo., P.O. Box 1, Krugersdorp, Transvaal.  
 Graham, Hon. T. Lyndoch, K.C., M.L.C., Sonnenstrahl, Wynberg, near Cape Town.  
 Graham, Mrs. T. Lyndoch, Sonnenstrahl, Wynberg, near Cape Town.  
 \*Grant, G. C., M.A., Principal, Public Schools, Graham's Town, Cape Colony.  
 Gray, Revd. James, The Manse, Visagie Street, Pretoria.  
 \*Greatbatch, Daniel Westwood, M.S.A., P.O. Box 195, Kimberley, Cape Colony.

- \*Greathead, Dr. J. B., Graham's Town, Cape Colony.
- Green, J. Dampier, P.O. Box 340, Johannesburg.
- \*Greenhill, H. H., M.Inst.C.E., B.A. (Camb.), P.O. Box 172, Bloemfontein.
- \*Greenlees, Thomas Duncan, M.B., Grahamstown, Cape Colony.
- \*Gregory, A. J., M.D., M.R.C.S., L.S.A., Parliament Street, Cape Town.
- \*Griffiths, Harry Denis, Assoc.M.Inst.C.E., A.R.S.M., M.Inst.M.M., M.I.Mech.E., M.S.A.A.E., P.O. Box 2146, Johannesburg.
- Grindley-Ferris, Vyvyan, Jumpers Deep Ltd., Cleveland, Johannesburg.
- Gyde, C. J., Public Works Department, Ermelo, Transvaal.
  
- Haddon, T. R., P.O. Box 956, Johannesburg.
- \*Hahn, Paul Daniel, Ph.D., M.A., Professor of Chemistry, South African College, Cape Town.
- \*Hall, R. J., Bloemfontein.
- Hall, R. N., F.R.G.S., Havilah Camp, Great Zimbabwe, Rhodesia.
- Hallimond, W. T., Jumpers Deep, Ltd., Cleveland, Johannesburg.
- Hamilton, J. G., P.O. Box 1048, Johannesburg.
- Hamilton, W. Stirling, Inspector of Mines Office, Krugersdorp, Transvaal.
- Hammersley-Heenan, Robert H., M.Inst.C.E., General Manager and Engineer-in-Chief to the Table Bay Harbour Board, Cape Town.
- Hanau, Carl, P.O. Box 433, Johannesburg.
- Hanau, Isidor, Silverhurst, Wynberg, near Cape Town.
- \*Hancock, H., Assoc.M.Inst.C.E., P.O. Box 192, Klerksdorp, Transvaal.
- °Hancock, Strangman, M.Amer.M.E., Jumpers Deep Ltd., Cleveland, Johannesburg.
- \*Harris, C., Graham's Town, Cape Colony.
- Hart, J. A., P.O. Box 204, Boksburg, Transvaal.
- Hazard, Erskine, Roodepoort Central Deep, Roodepoort, Transvaal.
- Head, John, Rosewarne, St. Andrew's Road, Park Town, Johannesburg.
- \*Heap, W. L., School of Mines, Kimberley, Cape Colony.
- \*Heatlie, Arthur, B.A.Camb., Assoc.M.Inst.C.E., District Engineer, Cape Government Railways, Queen's Town, Cape Colony.
- \*Hellmann, F., East Rand, Boksburg, Transvaal.
- \*Helmores, William Holloway, 23, Jones Street, Kimberley, Cape Colony.
- \*Henkel, J. S., District Forest Officer, Stutterheim, Cape Colony.
- Hennesy, A., City Club, Cape Town.
- \*Henrotin, Charles, Manager, Kimberley Mines, Kimberley, Cape Colony.
- Hess, J. P., P.O. Box 315, Pretoria.
- \*Heward, Richard H., C.E., Municipal Engineer, Sea Point, near Cape Town.
- Hewitt, Frank E., Education Department, Pretoria.
- Heyman, Richard, P.O. Box 2425, Johannesburg.

- Heywood, Arthur William, Conservator of Forests, Umtata, Transkei, Cape Colony.
- Hill, J. L., P.O. Box 393, Pretoria.
- Hill, Patrick Joseph, Architect, c/o Brennan & Hill, P.O. Box 16, Kimberley, Cape Colony.
- \*Hodge, E., Railway Engineer's Office, O'okiep, Namaqualand, Cape Colony.
- Hofmeyer, Hon. Jan Hendrick, Member Executive Council, 9, Camp Street, Cape Town.
- Holderness, J. C., P.O. Box 1135, Johannesburg.
- Holford, W. G., P.O. Box 2927, Johannesburg.
- Holtby, A. C., M.Inst.E.E., P.O. Box 4336, Johannesburg.
- Hooper, Henry Chartres, Department of Agriculture, Cape Town.
- \*Hopper, E., P.O. Box 550, Johannesburg.
- \*Horne, William James A. E., Assoc.M.Inst.E.E., F.R.S.S.A., South African College, Cape Town.
- \*Hough, Sydney Samuel, M.A., F.R.S., Royal Observatory, near Cape Town.
- Howard, Robert Nesbit, M.R.C.S., F.R.M.S., O'okiep, Namaqualand, Cape Colony.
- Hume, William, P.O. Box 1532, Johannesburg.
- \*Hutchins, David Ernest, F.R.Met.Soc., Conservator of Forests, Kolara, Kenilworth, near Cape Town.
- Hutt, E. W., P.O. Box 2862, Johannesburg.
- Ingle, Frederick, P.O. Box 1620, Johannesburg.
- Innes, Sir Jas. Rose, K.C.M.G., Chief Justice of the Transvaal, Pretoria.
- \*Innes, R. T. A., P.O. Box 858, Johannesburg.
- Jameson, Dr. Leander Starr, C.B., M.L.A., Groote Schuur, Rondebosch, near Cape Town.
- Jenkins, Rev. William Owen, M.A., Principal of the Diocesan College, Rondebosch, near Cape Town.
- Jennings, J. Hennen, 1, London Wall Buildings, London, E.C.
- \*Jennings, Sidney J., M.Amer.I.M.E., M.I.M.M., C.E.Harvard Univ., P.O. Box 149, Johannesburg.
- Jeppe, Julius, Danish and Greek Consulate General, Vredenburg, Liesbeek Road, Rosebank, near Cape Town.
- \*Johns, J. Harry, Assoc.M.I.C.E., M.I.M.M., P.O. Box 231, Johannesburg.
- Johnson, E. H., P.O. Box 1127, Johannesburg.
- Johnson, J. Paul, Jumpers Deep, Cleveland, Johannesburg.
- Johnson, Tom, Geldenhuis Deep, Cleveland, Johannesburg.
- \*Jones, Hon. Mr. Justice, Judge President, Eastern Districts Court, Graham's Town, Cape Colony.
- Jones, W. H., P.O. Box 204, Boksburg, Transvaal.
- Jourdan, C. J. N., P.O. Box 1952, Johannesburg.
- \*Jurisch, Captain Carl Heinrich Leopold Max, 21, Hof Street, Cape Town.

- Juritz, Charles Frederick, M.A., Government Analytical Laboratory.  
Cape Town.
- Juritz, Walter Daniel Christian, B.A., Villa Marina, Sea Point, near  
Cape Town.
- Juta, Sir Henry, Kt., K.C., M.L.A., Mon Desir, Mains Avenue.  
Kenilworth, near Cape Town.
- Juta, Lady, Mon Desir, Mains Avenue, Kenilworth, near Cape Town.
- Juta, Miss, Mon Desir, Mains Avenue, Kenilworth, near Cape Town.
- Kaufmann, Siegmund, M.D. Vienna, 46, Strand Street, Cape Town.
- Keen, A. A., 17, High Street, Woodstock, near Cape Town.
- Kelty, John Kenyon, M.A., Ceres Villa, Mount Nelson Road, Sea  
Point, near Cape Town.
- Kendall, Franklin Kaye, A.R.I.B.A., Rhodes Buildings, Cape Town.
- Kendall, Roland, P.O. Box 393, Pretoria.
- Kent, Professor Thomas Parkes, M.A., Diocesan College, Ronde-  
bosch, near Cape Town.
- \*Kilgour, G., P.O. Box 813, Cape Town.
- \*King-Salter, J. J., H.M. Naval Yard, Simon's Town, Cape Colony.
- \*Kirkland, J. W., B.Sc., P.O. Box 1905, Johannesburg.
- \*Knapp, A. D., Mbanga Estate, Blantyre Post Office, British Central  
Africa.
- \*Knight, D., J.P., Graham's Town, Cape Colony.
- \*Knox, E. B. J., M.Inst.C.E., A.R.I.B.A., M.S.A.A.A., P.O. Box 398.  
Johannesburg.
- Kolbe, Rev. F. C., B.A., D.D., S. Mary's Presbytery, Cape Town.
- Kotzé, R. N., M.E., B.A., P.O. Box 550, Johannesburg.
- Kynaston, H., M.A., F.G.S., P.O. Box 418, Pretoria.
- \*Laffan, G. B., 11, Hardy's Chambers, Maritzburg, Natal.
- Lance, W. F., P.O. Box 744, Johannesburg.
- Lancelot, Horace A. S., Assoc.M.Inst.M.E., Engineer's Office,  
Point, Durban, Natal.
- Laschinger, E. J., B.A.Sc., P.O. Box 2532, Johannesburg.
- \*Laughton, John, Town Engineer, Bulawayo, Rhodesia.
- Lavenstein, L. H., P.O. Box 4480, Johannesburg.
- \*Lawn, J. G., A.R.S.M., Assoc.M.Inst.C.E., F.G.S., P.O. Box 231,  
Johannesburg.
- Lawrence, Frederick James, Asst. Res. Magistrate, Lady Grey, dist.  
Aliwal North, Cape Colony.
- \*Leane, Walter Burditt, Prof. Assoc. Surveyors Inst., c/o Pauling &  
Co., Ltd., Cape Town.
- Leck, W., P.O. Box 1603, Johannesburg.
- Lee, Miss, Good Hope Seminary, Cape Town.
- Legat, C. E., P.O. Box 434, Pretoria.
- Legg, William Andrew, M.Inst.C.E., 6, St. George's Chambers, St.  
George's Street, Cape Town.
- Leitch, Donald Calder, M.Inst.C.E., P.O. Box 1049, Johannesburg.
- \*Lenz, Otto, P.O. Box 92, Johannesburg.
- Lepper, C. H., P.O. Box 1450, Johannesburg.

- \*Lesar, Louis W. G., Railway Accounting Department, Cape Town.
- Leslie, T. N., C.E., F.G.S.Lon., P.O. Box 23, Vereeniging, Transvaal.
- Leupold, H., P.O. Box 3535, Johannesburg.
- Lewis, Professor C. E., M.A., South African College, Cape Town.
- \*Lewis, Francis Samuel, M.A., South African Public Library, Cape Town.
- Lewis, Joseph, M.A. Camb., Government Analytical Laboratory, Cape Town.
- Lewis, Leon, P.O. Box 3320, Johannesburg.
- \*Liddell, J., Chief Mech. Engineer, De Beers Mines, Kimberley, Cape Colony.
- Ligertwood, F.G., Education Department, Pretoria.
- \*Lindley, J. B., C.M.G., M.A., LL.B., Claremont, near Cape Town.
- Littlewood, Edward Thornton, M.A., B.Sc., High School for Boys, Wynberg, near Cape Town.
- \*Logan, Thomas, Cape Government Railways, Cape Town.
- Logeman, William H., B.A.Cape, South African College, Cape Town.
- \*Logeman, Professor Willem Sybrand, Lit. Hum. Cand., B.A., South African College, Cape Town.
- Logie, Dr. T., Education Department, Cape Town.
- Long, Charles, Post Office, Pretoria.
- Loubser, Matthew Michael, Port Elizabeth, Cape Colony.
- Lounsbury, Chas. P., B.Sc., F.E.S., Department of Agriculture, Cape Town.
- Lowinger, Victor Alexander, Royal Observatory, near Cape Town.
- \*Lucas, Claude Davis, Govt. Surveyor, P.O. Box 45, Ermelo, Transvaal.
- Luckhoff, Jan, M.D.Edin., Rhodes Buildings, Cape Town.
- \*Lunt, Joseph, B.Sc., F.I.C., F.R.A.S., Royal Observatory, near Cape Town.
- Lyell, Capt. David, M.Inst.C.E., 47 Co. Royal Engineers, Potchefstroom, Transvaal.
- Lyle, James, M.A., Grey College, Bloemfontein.
- \*Lynch, Major F. S., Waterworks Company, Kimberley, Cape Colony.
- Lyon, Polhemus, Bloemfield, Highwick Avenue, Claremont, near Cape Town.
- \*Maierley, A. Lambert, 37, Transvaal Road, Kimberley, Cape Colony.
- \*Macdonald, W., M.S.Agr.Cornell, M.Sc.Cape, P.O. Box 434, Pretoria.
- \*Macfarlane, Donald, M.Inst.C.E., H.M. Naval Yard, Simon's Town, Cape Colony.
- Mackenzie, Professor Alexander Herbert, M.A., Victoria College, Stellenbosch, Cape Colony.
- \*Mackenzie, John Edffe, M.B. C.M., 34, Currey Street, Kimberley, Cape Colony.

- Mackenzie, T. K., P.O. Box 1876, Johannesburg.
- Mackinlay, A. G., C.E., M.San.I., Government Railway, Maritzburg, Natal.
- Mackinnon, N., P.O. Box 191, Germiston.
- \*Macmuldrow, W. G. P., P.O. Box 379, Cape Town.
- Mally, Charles William, M.Sc., Graham's Town, Cape Colony.
- Mansel, Robert, Assoc.M.Inst.C.E., Umbilo, near Durban.
- Marais, Leslie N., P.O. Box 881, Pretoria.
- \*Marloth, R., Ph.D., M.A., P.O. Box 359, Cape Town.
- Marshall, Guy Anstruther Knox, F.Z.S., F.E.S., P.O. Box 149, Salisbury, Rhodesia.
- Martin, Alfred J., P.O. Box 3904, Johannesburg.
- Masey, Francis Edward, F.R.I.B.A., Rhodes Buildings, Cape Town.
- Mason, W. G., B.Sc., F.H.A.S., Agricultural College, Elsenberg, Mulders Vlei, Stellenbosch, Cape Colony.
- \*Matesdorf, Ernest, 12, Wale Street, Cape Town.
- Mathew, J. A., President Pharmacy Board, Hazeldene, Sea Point, near Cape Town.
- Mathey, J. W. M. Van Dyk, P.O. Box 2950, Johannesburg.
- \*Matthews, Arthur, M.A., S. Andrew's College, Graham's Town, Cape Colony.
- \*McBean, D. Moore, Govt. Surveyor, 16, Old Main Street, Kimberley, Cape Colony.
- \*McBeath, John William, Chemist, Kimberley, Cape Colony.
- McClure, Rev. John James, Dalreada, Upper Orange Street, Cape Town.
- McDonald, F. R., Rand Club, Johannesburg.
- \*McEwen, T. S., Assoc.M.Inst.C.E., General Manager, Cape Government Railways, Cape Town.
- McLean, A., Sunnyside, Howick, Natal.
- McMillan, James Peter, Assoc.M.Inst.C.E., Graaff-Reinet, Cape Colony.
- McNaughton, Colin Beddoes, Forest Department, Knysna, Cape Colony.
- Meintjes, Harold Edwin Haffenden, Adelaide, Cape Colony.
- Melle, Dr. G. J. M., Mill Street, Lower Paarl, Cape Colony.
- Mellor, Edw. T., B.Sc., F.G.S., c/o Geological Survey Office, Pretoria.
- \*Melvill, E. H. V., P.O. Box 67, Johannesburg.
- \*Menmuir, R. W., Assoc.M.Inst.C.E., P.A.S.I., Town Engineer, Woodstock, near Cape Town.
- Mennell, Frederic Philip, F.G.S., Rhodesia Museum, Bulawayo, Rhodesia.
- \*Messer, E. H., P.O. Box 67, Johannesburg.
- o\*Metcalfe, Sir Charles, Bart., M.Inst.C.E., P.O. Box 588, Cape Town.
- \*Methven, C. W., Durban, Natal.
- \*Meyer, E. C. J., School of Mines, Kimberley, Cape Colony.
- Middleton, Orlando, A.R.I.B.A., 98, Mutual Buildings, Port Elizabeth, Cape Colony.

- \*Miller, Harry William, Assoc.M.Inst.C.E., M.I.Mech.E., M.Amer.I. Mining E., Past. Pres. S.A.A.E., c/o Cunningham & Gearing, Engineers, Cape Town.
- \*Mirrlees, W. J., 9, London Chambers, Durban, Natal.
- Mitchell, James Alexander, M.B., Ch.B., 33, Parliament Street, Cape Town.
- \*Mitchell, J. C., M.B., D.Sc., Bacteriological Institute, Graham's Town, Cape Colony.
- Mitchell, R. A., P.O. Box 228, Bulawayo, Rhodesia.
- Moffatt, J. A., P.O. Box 621, Johannesburg.
- Moir, James, M.A., D.Sc. (Aber.), F.C.S., 15, Esselen Street, Hospital Hill, Johannesburg.
- Monier-Williams, O. F., P.O. Box 1113, Johannesburg.
- \*Mordaunt, H. L., Cape Government Railways, Ceres Road, Cape Colony.
- \*More, J. R., District Engineer, Mafeking, Cape Colony.
- Morice, Advocate G. T., B.A. Oxford, P.O. Box 55, Johannesburg.
- Morrison, Professor John Todd, M.A., B.Sc., F.R.S.E., Assoc.M. Inst.E.E., Victoria College, Stellenbosch, Cape Colony.
- \*Mowbray, Ernest Wheldale, 10, Belgrave Road, Kimberley, Cape Colony.
- \*Muir, G. B., "Argus" Office, Cape Town.
- \*Muir, Thomas, C.M.G., LL.D., M.A., F.R.S.S.L. & E., Education Department, Cape Town.
- Muirhead, James Muirhead Potter, F.S.A.A., F.S.S., F.A.S.L., Selwyn Chambers, St. George's Street, Cape Town.
  
- Nash, Maynard, Cliff Villa, Protea Road, Newlands, near Cape Town.
- Nathan, Manfred, B.A., LL.B., LL.D., P.O. Box 1078, Johannesburg.
- Needham, G., c/o Lennon Limited, Adderley Street, Cape Town.
- \*Nel, P. Otto, School of Mines, Kimberley, Cape Colony.
- Nelson, W., Nelsonia, Johannesburg.
- \*Newcombe, T., 33, Mutual Buildings, Durban, Natal.
- \*Newdigate, William, Govt. Land Surveyor, c/o De Beers Consd. Mines, Ltd., Kimberley, Cape Town.
- \*Newey, Joseph, M.Inst.C.E., Public Works Department, Cape Town.
- \*Nicholson, George Taylor, M.Inst.C.E., Engineer's Office, Table Bay Harbour Works, Cape Town.
- Nitch, H. G., Rose Deep, Germiston, Transvaal.
- Niven, A. Mackie, P.O. Box 2365, Johannesburg.
- Nobbs, Eric A., Ph.D., B.Sc., F.H.A.S., Department of Agriculture, Cape Town.
- Norbom, John O., East Rand, Transvaal.
- \*Northcroft, G. A., Assoc.M.Inst.C.E., J.P., Margraf Street, Bloemfontein.
- Notcutt, Ernest Tiller Mursell, 15, Union Street, Cape Town.

- Oakley, H. M., Colonnade Buildings, Greenmarket Square, Cape Town.
- \*Oldfield, Francis, Waverley, Bloemfontein.
- Oldfield, Herbert, P.O. Box 537, Johannesburg.
- \*Oliver, H. A., Derwent House, Belgrave Road, Kimberley, Cape Colony.
- \*Orr, John, B.Sc., Whitworth Exhibitioner, Professor of Mechanical and Electrical Engineering, South African School of Mines, Kimberley, Cape Colony.
- \*Ortlepp, A. A., P.O. Box 1952, Johannesburg.
- Pakeman, R. J., P.O. Box 1020, Johannesburg.
- Park, Maitland, M.A., 3, Windsor Terrace, Gardens, Cape Town.
- \*Park, W. E., P.O. Box 619, Johannesburg.
- Parrott, Lieut.-Col. T. S., Goodman's Buildings, Johannesburg.
- \*Parsons, A. J., Cape Government Railways, Cape Town.
- \*Patrick, C. B., Assoc.M.Inst.C.E., Government Mining Inspector, Barberton, Transvaal.
- \*Pauling, P. J., Engineer, Cape Government Railways, Ceres Road, Cape Colony.
- Payne, Albert E., A.R.S.M. Lond., P.O. Box 231, Johannesburg.
- Pearce, S. H., M.I.M.M., P.O. Box 149, Johannesburg.
- Pearson, Professor Henry Harold Welch, M.A., F.L.S., South African College, Cape Town.
- Pedersen, L., Village Deep Ltd., Johannesburg.
- \*Peet, H. F., M.San.I., City Engineer, Bloemfontein.
- Pegram, Thomas H., Rondebosch, near Cape Town.
- Peirce, A. W. K., P.O. Box 217, Germiston, Transvaal.
- Péringuey, L., South African Museum, Cape Town.
- Perry, Thomas Weston, Engineer's Office, Public Works Department, Cape Town.
- Petersen, Ernest, Civil & Electrical Engineer, Consul for the Argentine Republic, Johannesburg, Bam's Buildings, 41, St. George's Street, Cape Town.
- Petersen, H. T., P.O. Box 1022, Johannesburg.
- \*Pettersson, Otto, W.P.M.Rifles, Malmesbury, Cape Colony.
- Philip, Thos., P.O. Box 112, Roodepoort, Transvaal.
- \*Phillips, William White, F.S.I., Govt. Surveyor, Savings Bank Buildings, St. George's Street, Cape Town.
- Pim, Howard, P.O. Box 1331, Johannesburg.
- Pim, Mrs. R. W., P.O. Box 1331, Johannesburg.
- Pink, Henry Frederick Lewis, Groote Schuur Forests, Rondebosch, near Cape Town.
- \*Pitchford, J. B., A.S.M.E., Randfontein, Transvaal.
- Pitts, John, P.O. Box 590, Johannesburg.
- Pizzighelli, R., P.O. Box 2706, Johannesburg.
- Playford, Louis L., P.O. Box 377, Johannesburg.
- Pohls, Mrs. A., P.O. Box 3745, Johannesburg.
- Pollard, F. (L., Princess Estate, Roodepoort, Transvaal.

- Pollitt, Robert B., Assoc.M.Inst.C.E., C.E., F.I.C., F.C.S., Assoc. M.Inst.E.E., De Beers Explosives Works, Somerset West, Cape Colony.
- \*Poore, G. B., M.I.Mech.E., M.I.M. & M.E., P.O. Box 149, Johannesburg.
- Porter, Dr. Chas., M.D., B.Ch., M.R.C.S. Eng., D.P.H. Camb., of Gray's Inn, Barrister at Law, P.O. Box 1049, Johannesburg.
- \*Porter, C. L., Manager, Premier Mine, Wesselton, Kimberley, Cape Colony.
- Posnett, Dr. W. G. Tottenham, F.R.C.S.I., P.O. Box 3353, Johannesburg.
- \*Powell, Dr. A. B. S., Fort England, Graham's Town, Cape Colony.
- Power, J., Surveyor, 12, Wale Street, Cape Town.
- Preston, James, Main Road, Mowbray, near Cape Town.
- Price, C. J., P.O. Box 1056, Johannesburg.
- \*Price, T. R., C.M.G., J.P., General Manager, Central South African Railways, Johannesburg.
- Prior, Ferdinand, Candidatus philosophiae, Consul for Denmark, P.O. Box 1005, Johannesburg.
- Pybus, W. H. Lawson, Government Railway, Maritzburg, Natal.
- \*Quentrall, Thomas, F.G.S., M.I.Mech.E., Kimberley Club, Kimberley, Cape Colony.
- Quinan, Kenneth B., Chemist and Engineer, De Beers Explosives Works, Somerset West, Cape Colony.
- \*Quinan, W. R., De Beers Explosives Works, Somerset West, Cape Colony.
- Quinn, J. W., J.P., P.O. Box 1454, Johannesburg.
- Ramberg, Baron, Acting Consul-General for Austria-Hungary, P.O. Box 662, Cape Town.
- \*Ransome, George, A.R.I.B.A., Colonial Orphan Chamber Buildings, 4, Church Square, Cape Town.
- Rathbone, E. P., M.I.M. & M., Assoc.M.Inst.C.E., M.S.A.A.E., P.O. Box 927, Johannesburg.
- Rattray, George, M.A., B.Sc., F.R.S.G.S., Boys' High School, Wellington, Cape Colony.
- \*Reeve, Thomas, Harbour Board, Port Elizabeth.
- Reich, Gustav Charles, 7, Orphan Street, Cape Town.
- \*Reid, Arthur Henry, F.R.I.B.A., P.O. Box 120, Cape Town.
- \*Reid, Walter, P.O. Box 746, Johannesburg.
- Reilly, Edward P., M.Inst.C.E., Mem.Soc.Arts., Engineer and General Manager, Gas Works, Cape Town.
- \*Reunert, Frederick, P.O. Box 432, Kimberley, Cape Colony.
- \*Reunert, Theodore, M.Inst.C.E., M.I.Mech.E., P.O. Box 92, Johannesburg.
- Reyersbach, L., P.O. Box 149, Johannesburg.
- \*Reynolds, C. G., Commissioner Public Works Office, Cape Town.

- Reynolds, H. F., P.O. Box 1085, Pretoria.  
 Richardson, Alex., F.R.G.S., P.O. Box 559, Johannesburg.  
 Ritchie, Professor William, M.A. Aberdeen, M.A. Oxon., South African College, Cape Town.  
 \*Ritso, Bernard William, M.Inst.C.E., F.G.S., Public Works Department, Cape Town.  
 \*Robarts, W. E., Durban, Natal.  
 \*Robbins, Percy Arthur, M.E., c/o De Beers Consd. Mines. Ltd., Kimberley, Cape Colony.  
 \*Roberts, Alexander William, D.Sc., F.R.A.S., F.R.S.E., Lovedale, Cape Colony.  
 \*Roberts, C. T., Assoc.M.Inst.C.E., Salisbury, Rhodesia.  
 Roberts, Frank, P.O. Box 479, Pretoria.  
 Robertson, James, Vice-Principal, High School for Boys, Wynberg, near Cape Town.  
 Robertson, John, P.O. Box 1313, Johannesburg.  
 Robertson, William, M.R.C.V.S., Edgehill, Wynberg, near Cape Town.  
 Robinson, J., P.O. Box 2638, Johannesburg.  
 Robinson, John Henry, Stationer, Lower St. George's Street, Cape Town.  
 Robson, T. Conyers, P.O. Box 946, Pretoria.  
 Rodger, James, M.A., Glasgow, Education Office, Cape Town.  
 Rogers, Arthur William, M.A., F.G.S., South African Museum, Cape Town.  
 \*Rogers, F.C., P.O. Box 392, Kimberley, Cape Colony.  
 Rogers, Lincoln C., Randfontein Estates, Randfontein, Transvaal.  
 Rohmann, Martin, Transvaal Telegraphs, G.P.O., Johannesburg.  
 \*Rose, James Wilmot Andreas, Assoc.M.Inst.C.E., Resident Engineer, C.S.A.R., Pretoria.  
 Rose, John G., Government Analytical Laboratory, Cape Town.  
 Ross, George, P.O. Box 646, Johannesburg.  
 \*Ross, Robert Charles, 28, Stockdale Street, Kimberley, Cape Colony.  
 Rossiter, Lance W., P.O. Box 407, Johannesburg.  
 Rouliot, G., P.O. Box 149, Johannesburg.  
 Roux, Philip R., P.O. Box 928, Johannesburg.  
 Rugg, Hugh, P.O. Box 1049, Johannesburg.  
 \*Runciman, William, M.L.A., Simon's Town, Cape Colony.  
 Russell, A. Gordon, Assoc. King's College, London, C.E., Assoc. M.S.A.A.E., P.O. Box 3142, Johannesburg.  
 Russell, Miss J. M., P.O. Box 3613, Johannesburg.  
 Rutherford, A., Main Road, Wynberg, near Cape Town.  
 Salmon, Albert Eburn, South African Art Gallery, Cape Town.  
 Sauer, C. B., M.S.A.A.E., A.I.M.E., P.O. Box 1056, Johannesburg.  
 \*Sargent, E. B., M.A. Trinity Coll. Cambridge, P.O. Box 2641, Johannesburg.  
 \*Scaife, Thomas Earle, Assoc.M.Inst.C.E., Breede River Irrigation Works, Robertson, Cape Colony.

- ~~Seimund~~ Selmar, Hon.M.A. Oxon., Ph.D., F.L.S., C.M.Z.S.,  
Director of the Albany Museum, Graham's Town, Cape Colony.
- ~~Seimund~~ G., P.O. Box 3391, Johannesburg.
- ~~Seimund~~ R. W., P.O. Box 149, Johannesburg.
- ~~Seimund~~ Ernest H. L., A.R.C.S., F.G.S., South African Museum,  
Cape Town.
- ~~Seimund~~ William Lutley, M.A. Oxon., South African Museum, Cape  
Town.
- Sest, Herbert S., B.A., Education Department, Pretoria.
- Seddy, William Charles, Hon. Fellow Edin. Univ., Bredasdorp,  
Cape Colony.
- \*Sedgwick, Capt. E. W., Bay View, Anson Road, Observatory Road,  
near Cape Town.
- Seller, Alfred Edward, L.S.A. Lond., 117, Hanover Street, Cape  
Town.
- Shand, Alexander, Assoc.M.Inst.C.E., Cape Divisional Council,  
Cape Town.
- Shanks, R., P.O. Box 1313, Johannesburg.
- \*Shannon, J. D., District Engineer's Office, Salt River, near Cape  
Town.
- Sharp, Jerome, P.O. Box 3075, Johannesburg.
- Sheel, E. W., Chief Engineer to Sir John Jackson, Ltd., Simon's  
Town, Cape Colony.
- Shepherd, Percy G., P.O. Box 646, Johannesburg.
- \*Sheppard, Ernest, c/o Major Gorle, A.S. Corps, Kimberley, Cape  
Colony.
- \*Shores, J. W., M.Inst.C.E., C.M.G., Engineer-in-Chief, Natal Gov-  
ernment Railway, Maritzburg, Natal.
- Shortridge, Guy Chester, South African Museum, Cape Town.
- Sieg, Hans, Savings Bank Buildings, St. George's Street, Cape  
Town.
- Sinclair, St. Clair Overbeek, M.A., Government Analytical Labora-  
tory, Cape Town.
- Slead, C. G. H., c/o Forbes & Edenborough, Port Elizabeth, Cape  
Colony.
- Skinner, H. R., Roodepoort, Transvaal.
- Skinner, W., Rietfontein "A," Ltd., Johannesburg.
- \*Slater, J., B.A., Graham's Town, Cape Colony.
- \*Smartt, Hon. Dr. T. W., M.L.A., Cape Town.
- \*Smith, A. B., P.O. Box 90, Queen's Town, Cape Colony.
- \*Smith, Fred., F.C.S. London, M.S.C.I., M.S.A.A.E., A.M.I.M. & M.,  
P.O. Box 1324, Johannesburg.
- Smith, James, M.A., Normal College, Cape Town.
- Smith, Hon. Jus. Sir W. J., Pretoria.
- Smith, Walter Henry, Mech. Eng., Public Works Department, Cape  
Town.
- Smith, William George, Totteridge, Pillans Road, Rosebank, near  
Cape Town.
- Smits, W. S., P.O. Box 1167, Johannesburg.
- Smyth, H. Warrington, Mines Department, Johannesburg.

- Solly, Hubert le Gay, Assoc.M.Inst.C.E., Knor Hoek, Sir Lowry's Pass, Cape Colony.
- Solly, Mrs. Julia F., Knor Hoek, Sir Lowry's Pass, Cape Colony.
- Solomon, Hon. Jus. W. H., High Court, Pretoria.
- \*Sparrow, W. B., Cape Government Railways, Ceres Road, Cape Colony.
- Spengel, H., P.O. Box 3498, Johannesburg.
- Spoor, Alfred L., P.O. Box 668, Johannesburg.
- Sprigg, Miss, Kensington Flats, Johannesburg.
- \*Stanford, Frederick Owen, A.K.C. Lond., Assoc.M.Inst.C.E., H.M. Dockyard Extension, Simon's Town, Cape Colony.
- Stark, H. F., P.O. Box 1081, Johannesburg.
- Stephens, F. C., A.M.I.E.E., Public Works Department, Pretoria.
- \*Stephens, F. O., M.Inst.C.E., P.O. Box 713, Cape Town.
- Stephens, Henry Errington, Alma Road, Rosebank, near Cape Town.
- Stevens, James Daniel, A.Inst.E.E., P.O. Box 691, Cape Town.
- Stevenson, E. Sinclair, M.D., Ch.D., F.R.C.S.E., Strathallan, Rondebosch, near Cape Town.
- Stevenson, Miss Elizabeth, Good Hope Seminary, Cape Town.
- \*Stewart, Charles M., B.Sc., Meteorological Commission, Cape Town.
- \*St. Leger, Robert A., M.B., C.M., c/o "Cape Times," Cape Town.
- \*Stockman, H. R., Admiralty Harbour Works, Simon's Town, Cape Colony.
- \*Stocks, R. R., Graham's Town, Cape Colony.
- \*Stone, Miss Elizabeth Spencer, Training Institute, Queen Victoria Street, Cape Town.
- Stonestreet, G. D., Inspector of Mines, Krugersdorp, Transvaal.
- Storer, Felix, P.O. Box 1095, Pretoria.
- \*Stott, Clement H., F.G.S., M.S.A., F.S.I., P.O. Box 7, Maritzburg, Natal.
- Stroud, James Wm., M.D., F.L.S., F.G.S. Lon., P.O. Box 323, Pretoria.
- Stubbs, J. W. H., P.O. Box 1488, Johannesburg.
- \*Sutton, John Richard, M.A. Camb., P.O. Box 142, Kimberley, Cape Colony.
- \*Sutton, L. B., P.O. Box 45, Randfontein, Transvaal.
- Symonds, Dr. Edmond, M.R.C.S., L.R.C.P. Lon., Kroonstad, Orange River Colony.
- Symons, Robert Fox, Medical Officer of Health, Government Buildings, Pretoria.
- Taylor, Lionel Edward, Forest Department, Cape Town.
- Theobald, C. E., Dynamite Factory, Modderfontein, Transvaal.
- Thom, John, P.O. Box 1145, Johannesburg.
- Thom, Mrs. J. R., P.O. Box 4022, Johannesburg.
- Thomas, Charles Neumann, Assoc.M.Inst.C.E., The Anchorage, Kalk Bay, near Cape Town.
- Thomas, Miss Ethel Neumann, The Anchorage, Kalk Bay, near Cape Town.

- Thomas, T., P.O. Box 2025, Johannesburg.  
 Thomas, Walwyn, M.B., B.C., B.A. Camb., City Club, Cape Town.  
 Thompson, W. C., P.O. Box 485, Johannesburg.  
 \*Thompson, W. Wardlaw, Department of Agriculture, Cape Town.  
 Thomson, Professor William, M.A., B.Sc., F.R.S.E., University  
 Offices, Cape Town.  
 Thorne, W., J.P., Mayor of Cape Town.  
 \*Thornton, John Miller, M.Inst.C.E., Sandilli House, Uitenhage,  
 Cape Colony.  
 • Thurston, G. H., P.O. Box 67, Johannesburg.  
 Thwaites, Dr. J. A., P.O. Box 1654, Johannesburg.  
 Tietz, Heinrich, Ph.D., B.A., Vista, Belvliet Park, Observatory  
 Road, near Cape Town.  
 \*Tilney, John Deane, I.S.O., M.Inst.C.E., East London, Cape  
 Colony.  
 \*Tomony, Dr. W. M., Medical Officer of Health, Bloemfontein.  
 Tosh, William, M.I.Mech.E., J.P., P.O. Box 2392, Johannesburg.  
 \*Townsend, Stephen Frank, C.E., Chief Resident Engineer and  
 Agent, Rhodesia Railways, Ltd., Bulawayo, Rhodesia.  
 \*Treeby, P. E., P.O. Box 534, Johannesburg.  
 Treloar, P.Q., P.O. Box 112, Roodepoort, Transvaal.  
 Trill, Fred E., A.Inst.E.E., Glenara, Rondebosch, near Cape Town.  
 \*Trill, George William Charles, Hetherton Road, off Palmyra Road,  
 Newlands, near Cape Town.  
 Tripp, George Dixon, M.A., Fern Cottage, Camp Ground Road,  
 Rondebosch, near Cape Town.  
 \*Tucker, R., School of Mines, Kimberley, Cape Colony.  
 Tucker, W. K., C.M.G., P.O. Box 9, Johannesburg.  
 \*Tudhope, Alfred Dryden, Assoc.M.Inst.C.E., Government Land  
 Surveyor, Anela, Selwyn Road, Kenilworth, near Cape Town.  
 \*Tudor, William, Manager, De Beers Consd. Mines, Ltd., Kimberley,  
 Cape Colony.  
 Turner, Dr., P.O. Box 356, Pretoria.  
 Turton, Jno., P.O. Box 117, Barberton, Transvaal.  
 Tutton, F., P.O. Box 1049, Johannesburg.  
 Tweddill, Samuel M., M.S.A.L., F.G.S., P.O. Box 677, Pretoria.  
 \*Tyrrell, E. G. Harcourt, P.O. Box 135, Maritzburg, Natal.  
 \*Tyrrell, Colonel F., M.Inst.C.E., East London, Cape Colony.
- Upton, A. S., P.O. Box 619, Johannesburg.  
 Upton, Prescott, P.O. Box 1026, Johannesburg.
- Van der Riet, Professor Berthault de St. Jean, M.A., Ph.D., Victoria  
 College, Stellenbosch, Cape Colony.  
 Vaughan, J. A., R.N., Retd., P.O. Box 1104, Johannesburg.  
 \*Vines, C. Granville, Borough Electrical Engineer, Kimberley, Cape  
 Colony.  
 \*Viney, Arthur E., P.O. Box 3233, Johannesburg.

- \*Visser, W. H., School of Mines, Kimberley, Cape Colony.  
 Von Dessauer, A., M.E. (Freiburg), P.O. Box 2083, Johannesburg.  
 Von Lindequist, Fr., Consul General for the German Empire, Mount Pleasant, The Avenue, Newlands, near Cape Town.  
 Von Oppell, Otto Karl Adolf, Rocklands Terrace, Upper Buitenkant Street, Cape Town.  
 \*Voskule, G. A., School of Mines, Kimberley, Cape Colony.
- Walker, Hubert William, A.R.I.B.A., 11, Main Street, Port Elizabeth, Cape Colony.  
 Walker, Murray, Assoc.M.Inst.C.E., Littlethorpe, Kenilworth, near Cape Town.  
 Walker, Rev. Thomas, M.A., LL.D. Edin., Victoria College, Stellenbosch, Cape Colony.  
 Wallace, William Macgregor, Wh.Sc., A.R.C.S., Victoria College, Stellenbosch, Cape Colony.  
 \*Waller, A. H., Assoc.M.Inst.C.E., F.R.Met.Soc., Town Hall, Durban, Natal.  
 \*Wallis, H., District Engineer, Bulawayo, Rhodesia.  
 \*Walsh, Albert, Brackley, Cumnor Road, Kenilworth, near Cape Town.  
 Ward, A. E., P.O. Box 191, Germiston, Transvaal.  
 Watermeyer, James, Windhoek, German S.W. Africa, *via* Swakopmund.  
 Waterston, Dr. Jane, Parliament Street, Cape Town.  
 \*Watkins, Arnold Hirst, M.D., M.R.C.S., Ingle Nook, Kimberley, Cape Colony.  
 Watson, John Craig, Assoc.M.I.Mech.E., P.O. Box 149, Johannesburg.  
 Waugh, Edward H., P.O. Box 1049, Johannesburg.  
 Way, Edward J., Assoc.M.Inst.C.E., F.I.C. Eng., Benoni, Transvaal.  
 \*Webb, H. H., M.Inst.C.E., M.I.M. & M., P.O. Box 67, Johannesburg.  
 \*Webb, T., Graham's Town, Cape Colony.  
 Webner, H., c/o Rolfes, Nobel & Co., Port Elizabeth, Cape Town.  
 \*Webster, G. W., Farm Samaria, Kimberley, Cape Colony.  
 Webster, Richard Arthur, C.E., P.W.Dept., Ndabeni Location, Uitvlugt, near Cape Town.  
 Wege, P. J., Clonave, Indian Road, Wynberg, near Cape Town.  
 Weiskopf, E., Dynamite Factory, Modderfontein, Transvaal.  
 Welton, Horace, Government Mining Engineer, Johannesburg.  
 Wells, Alex. S., M.A., M.B., F.R.C.S. Edin., 8, Queen Victoria Street, Cape Town.  
 Welsh, Arthur Bransby, B.A. Cape. South African College, Cape Town.  
 Wessels, Mr. Justice, Pretoria.  
 \*Wessels, Jno. J., Cape Univ. M.E.Dip., P.O. Box 178, Germiston, Transvaal.

- West, Faraday, Port Elizabeth, Cape Colony.  
 West, J. G., P.O. Box 1629, Johannesburg.  
 \*West, Oliver, Coombe Villa, Cape Road, Port Elizabeth, Cape Colony.  
 \*Westhofen, W., M.Inst.C.E., Public Works Department, Cape Town.  
 \*Whale, R. H., School of Art, Queen Victoria Street, Cape Town.  
 Wheeler, J. E., c/o Heynes, Mathew & Co., Cape Town.  
 \*Whitaker, George Reginald, District Engineer, Cape Government Railways, East London, Cape Colony.  
 Whitaker, W. H., Natal Government Railway, Maritzburg, Natal.  
 \*White-Cooper, William, M.A., F.R.I.B.A., Graham's Town, Cape Colony.  
 \*White, Franklin, P.O. Box 669, Bulawayo, Rhodesia.  
 White, H. B., P.O. Box 41, Springs, Transvaal.  
 White, Miss Francis Margaret, Trescoe, Cornwall Place, Wynberg, near Cape Town.  
 White, Miss Henrietta Mary, B.A. Cape, Trescoe, Cornwall Place, Wynberg, near Cape Town.  
 Wight, A., P.O. Box 122, Johannesburg.  
 Wilkinson, D., A.R.S.M., P.O. Box 3890, Johannesburg.  
 \*Williams, Alpheus Fuller, B.S. Mining Engineer, Acting-General Manager, De Beers Consd. Mines, Ltd., Kimberley, Cape Colony.  
 Williams, D., Linda Villa, Rondebosch, near Cape Town.  
 \*Williams, Ernest, Assoc.M.Inst.C.E., M.I.M. & M., P.O. Box 965, Johannesburg.  
 \*Williams, Gardner F., De Beers Consd. Mines, Ltd., Kimberley, Cape Colony.  
 \*Williams, J. R., M.I.M.M., M.Amer.I.M.E., P.O. Box 149, Johannesburg.  
 \*Williams, Dr. T., Graham's Town, Cape Colony.  
 Wilman, Miss M., South African Museum, Cape Town.  
 \*Wilmot, Hon. Alexander, M.L.C. Cape Colony, K.S.G., F.R.G.S., Houses of Parliament, Cape Town.  
 Wilmot, Louis B., A.I.E.E., P.O. Box 5, Knights, Johannesburg.  
 \*Wilms, L. A., A.M.I.E.E., M.S.A.A.E., P.O. Box 88, East Rand, Transvaal.  
 Wilms, Mrs. L., P.O. Box 88, East Rand, Transvaal.  
 °Wilson, Arthur Marius, M.D., B.S., L.R.C.P., M.R.C.S., Jesmond House, Hof Street, Cape Town.  
 \*Wilson, E. M., Sir Lowry's Pass-Caledon Railway, P.O. Houw Hoek, Caledon, Cape Colony.  
 \*Wilson, John Fairweather, Assoc.M.Inst.C.E., H.M. Dockyard Extension Works, Simon's Town, Cape Colony.  
 Wilson, L. H., Assoc.M.I.Mech.E., Public Works Department, Pretoria.  
 \*Wilson, N., East Rand, Johannesburg.  
 °Winterton, Albert Wyle, F.C.S. Lond., Mem. Iron and Steel Inst. G.Brit., Lemoenfontein, near Beaufort West, Cape Colony.  
 Wood, John, Bank of Africa House, East London, Cape Colony.  
 Wood, J. H., Kalk Bay, near Cape Town.

- Woodhead, W. Spivey, P.O. Box 542, Cape Town.  
\*Wybergh, W., Commissioner of Mines, Johannesburg.  
\*Wynne-Roberts, R. O., Assoc.M.Inst.C.E., Water Engineer. Cape Town.
- Yallop, James Allan, Alandale, London Road. Sea Point, near Cape Town.  
Yates, John. A.R.S.M., F.G.S., P.O. Box 231, Johannesburg.  
Yeatman, Pope E. M., Randfontein. Johannesburg.  
Young, Professor Andrew. M.A., B.Sc., F.C.S., South African College. Cape Town.
-

Cullen, Mrs. W., Dynamite Factory, Modderfontein, Transvaal.  
 Douglass, Mrs. Arthur, Buana Vista, Wynberg, near Cape Town.  
 Douglass, Miss, Buana Vista, Wynberg, near Cape Town.  
 Dubois, Mrs. Raymond, Indian Road, Wynberg, near Cape Town.  
 Dyer, Mrs. Bertram L., Kimberley, Cape Colony.  
 Emanuel, Miss, Royal Observatory, near Cape Town.  
 Fremantle, Mrs. H. E. S., Bedwell Cottage, Rosebank, near Cape Town.  
 Fuller, Mrs. E. Barnard, Hawthornden, Rosmead Avenue, Hox Street, Cape Town.  
 Gill, Lady, Royal Observatory, near Cape Town.  
 Glendinning, Miss J. A., c/o W. Westhofen, Esq., Wynberg.  
 Hahn, Miss, York House, Upper Orange Street, Cape Town.  
 Hahn, Miss C., York House, Upper Orange Street, Cape Town.  
 Hutchins, Mrs. D. E., Kolara, Kenilworth, near Cape Town.  
 Johnston, H., Craig Royston, Wynberg, near Cape Town.  
 Lee, Miss, 117, Hanover Street, Cape Town.  
 Lewis, Mrs. C. E., Cape Town.  
 Lewis, Miss, Cape Town.  
 Logeman, Mrs. W. S., Cape Town.  
 Lyon, Mrs. Polhemus, P.O. Box 8, Cape Town.  
 Mally, L., York House, Upper Orange Street, Cape Town.  
 Perry, Mrs. T. Weston, Cape Town.  
 Pollitt, Mrs. R. B., De Beers Explosives Works, Somerset West, Cape Colony.  
 Powell, Fred, Royal Observatory, near Cape Town.  
 Prentice, Mrs. Manning, De Beers Explosives Works, Somerset West, Cape Colony.  
 Rawbone, Mrs. J., Broadlands, Sir Lowry's Pass, Cape Colony.  
 Reid, Mrs. Arthur H., Mannamead, Kenilworth, near Cape Town.  
 Ritchie, Mrs. W., Cape Town.  
 Salmon, Mrs. A. E., Cape Town.  
 Scully, Mrs. W. C., Bredasdorp, Cape Colony.  
 Seller, Mrs. A. E., 117, Hanover Street, Cape Town.  
 Truter, Mrs., c/o Miss Wilman, South African Museum, Cape Town.  
 Tudhore, Mrs. A. D., Anela, Selwyn Road, Kenilworth, near Cape Town.

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